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JOURNAL OF THE AERONAUTICAL SCIENCES

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# Nearing the Stratosphere

D. W. TOMLINSON, *Transcontinental & Western Air*

*Presented at a Session of the I. Ae. S.*
*at the Annual Meeting of the American Association for the Advancement of Science*
*December 28, 1937*

THERE has been a great deal of thought and study given to the problem of high altitude flying. Along with the conscientious efforts of competent scientists, imaginative souls have transferred their fondest dreams to the stratosphere as sort of an aviation millennium. These fantasies have misled the lay public until the average man on the street expects next year, or the year after, to travel in the stratosphere around the world at 1000 m.p.h. The research flying carried on by TWA has barely entered a wedge into an unknown realm, however, sufficient factual data and positive experience have been obtained to carry this work further with a sound concept of the economic possibilities and technical problems involved.

When, in the fall of 1934, it was decided to look into the future of high altitude flying, the principal objectives were: (1) to choose the best method of supercharging to 20,000 ft. and above, and equip an engine for rated power operation at 30,000 ft.; (2) determine the actual increase of speed with altitude as a check against theory; (3) make actual measurements of speed at 30,000 ft. to further check computed true air speeds; and (4) make extended cross country flights "over weather" to determine force and direction of winds and meteorological conditions at the base of the stratosphere. Objectives 1, 2, and 3 have been accomplished, enough experience has been had in the course of "over weather" flights to show how little is known about conditions at high levels above storm conditions.

## Supercharging Methods

Choice of a supercharging method lay between the gear driven impeller and the exhaust turbine as the motive power for the impeller. Aside from the flying done by Wiley Post with the "Winnie Mae," which had a Wasp engine equipped with a gear driven supercharger, no other high altitude flying of any duration had been accomplished in the country with this type of supercharger. On the other hand, the U. S. Army Air Corps had been carrying on the exhaust turbine supercharger development almost since the War.

Whereas the gear driven supercharger reaches maximum efficiency at only *one* cruising altitude the flexibility of the turbine supercharger enables a pilot flying above the critical cruising altitude of the unsupercharged engine at full throttle to utilize the turbine supercharger as desired, always cruising at full engine throttle. In this case the engine power diverted to supercharging is limited to that actually required above the energy recaptured from the exhaust gas. The principle disadvantages of the geared supercharger are the low power available for take-off at sea level and the ever present frictional losses in the mechanical gearing regardless of the required degree of supercharging.

Stratosphere tests were made possible through the collaboration of the United States Army Air Corps and the General Electric Company.

The first turbine unit was received early in 1936, and installed in a Northrop Gamma airplane powered with

a special direct drive Cyclone "G" engine. A three-bladed Hamilton Standard constant speed propeller was used. The usual installation and mechanical difficulties of any new project prolonged the test period which continued until the stratosphere flight from Kansas City to New York on January 24, 1937, after which the turbine supercharger was temporarily removed to make the Gamma available for other engine tests.

Significant phases and results of the test program follow.

### Oxygen System

The oxygen equipment consisted of a 15 liter liquid oxygen bottle and two light weight gaseous oxygen bottles of 39 cu.ft. capacity each. The liquid oxygen container was located in the observer's cockpit with a hot air blast directed against the evaporating coils. This hot air, also the cockpit heat, came from the intensifier tubes in the exhaust manifold formerly used for carburetor heat, now unnecessary because of the turbine supercharger. Cold oxygen gas from the evaporator could either be routed through an oxygen heating coil located in the hot air discharge from the intensifier tubes, or bypassed directly to the crew. In practice, the valves to the heater and the bypass were adjusted so that the resulting mixture of heated and cold oxygen produced a temperature at the breathing outlets of about 60°F.

All the oxygen controls were handled by the pilot, except the master valves at the oxygen bottles and the reducing valves which controlled the line pressure from the bottles; these valves were operated by the observer. Four valves and a pressure gage, conveniently grouped in the pilot's cockpit, comprised the main controls. These valves were:

(1) Primer valve, used to employ bottle pressure to quickly boost the pressure in the liquid oxygen flask and accelerate flow of liquid oxygen into the evaporating coils.

(2) Bottle oxygen valve which put bottle oxygen into the breathing system.

(3) Liquid oxygen valve which put oxygen gas from evaporating coils into the breathing system.

(4) Relief valve which controlled the pressure in the liquid oxygen flask, thus determining the rate of flow of liquid oxygen into the evaporating coils and hence the volume and pressure of oxygen available at the breathing outlets.

The practice was to use bottle oxygen for flights of less than two hours duration, and, as an emergency supply to supplement the liquid oxygen; for longer flights the liquid oxygen was used. By boosting the pressure in the liquid oxygen flask to 15 lbs. prior to take-off, there would be adequate evaporated oxygen available in ten minutes. On several occasions when cruising above 35,000 ft. it was necessary to cut in the bottle oxygen from time to time to insure an adequate supply, inasmuch as at these levels the crew had to breathe pure oxygen. Also during rapid descents from high levels bottle oxygen was used when, due to increase in atmospheric pressure, the evaporation rate of the liquid oxygen markedly decreased and the output of the vaporizing coils was no longer sufficient to supply the needs of the pilot and observer.

This oxygen equipment was capable of maintaining normal human efficiency to altitudes of 35,000 ft. only under conditions of almost complete inactivity. Even when breathing pure oxygen a marked degree of oxygen want existed above 30,000 ft. such that a slight decrease in oxygen pressure or moderate activity produced a comatose condition. Although fairly satisfactory for test purposes this oxygen installation would not be satisfactory for routine operations above 30,000 ft.

Complete loss of the oxygen supply at 30,000 ft. produces great mental and physical inefficiency in from 30 to 60 seconds and causes complete unconsciousness in 60 to 90 seconds. Prolonged moderate oxygen want or severe oxygen want for a relatively short period causes mental retardation and confusion for 30 minutes or longer after the oxygen want has been relieved. This latter effect is insidious and very hazardous; because of it, a pilot can unwittingly get in serious difficulty. This condition is almost invariably critical toward the end of flights at high altitudes and it is at the end of a flight when approaching a destination on instruments involving radio orientation and descent through thousands of feet of clouds that a pilot needs his faculties to be keen and reliable.

In connection with the observed fact of oxygen want, the writer experienced several instances during instrument approach to destination in which increased sensitivity of hearing during descent, combined with mental retardation, resulted in complete misinterpretation of radio beam signals. Clearing of ears by swallowing during descent, plus improving sense of hearing due to recovery from oxygen want, makes a fading radio signal sound as though it were actually increasing. This is a condition to be guarded against when descending from high altitude at any time, if using a radio range station for orientation and approach.

### Fuel Pressure

The early flights were devoted to smoothing out the turbo operation and finding means of maintaining adequate fuel pressure at levels above 20,000 ft. The steps taken to provide fuel pressure up to 35,000 ft. were:

(1) The $^1/_2$ in. and $^5/_8$ in. diameter fuel lines from the tanks to the fuel pump, were changed to $^3/_4$ in. diameter.

(2) The fuel pump was placed outside and below the bottom of the fuselage to increase the head to the pump.

(3) The three left wing tanks were connected to the vacuum pump discharge with appropriate relief valve, valves for controlling the pressure and two manifold pressure gages, one to atmosphere and the other to the

tanks in order that desired differential pressure could be maintained by observation of these gages.

(4) Two Romec F-4 fuel pumps connected in parallel.

Thus equipped, it was necessary to use air pressure on the fuel tanks above 22,000 ft. when using full power. On take-off the fuel pressure was 4 lbs.; at 22,000 ft., it had decreased to $1^1/_2$ lbs. The application of air pressure to the tanks caused the fuel pressure rise to $2^1/_2$ lbs. (full power operation) and maintain this pressure to 35,000 ft. Cruising at 500 hp. at 35,000 ft. the fuel pressure, with boost on the tanks, was $4^1/_2$ lbs. Without the boost on the tanks, the fuel pressure was $2^1/_2$ lbs. at which the engine operated satisfactorily.

It is apparent that fuel supply is a serious problem in the stratosphere. Not only is the matter of fuel pressure difficult but also the matter of evaporation is a question of unknown proportions. It is definitely known that fuel pumps must be completely drowned, preferably electrically or hydraulically driven and located in the bottom of the tanks. Evaporation losses are not known. However, as such loss is inescapable with present fuels, it will be necessary before extensive operating is done at stratosphere levels, to develop a less volatile fuel, or to pressurize the fuel tanks along with the cabin even though pressure in fuel tanks is definitely undesirable.

### Power Plant Operation

The control of the turbine supercharger was by means of an automatic pressure regulator. This device utilizes a sylphon and a differential oil piston employing engine oil pressure to control the exhaust waste gate, which in turn controls the amount of exhaust gases passing through the turbine, hence the speed of the turbine wheel and the impeller which is on the same shaft. The sylphon is connected to the carburetor inlet (intercooler discharge pressure) and to atmospheric pressure. It was set at the beginning of the tests to maintain at the carburetor either a pressure of 30 in. Hg or 26 in. Hg, the latter for cruising. Either pressure could be selected by the pilot using a control in the rear cockpit. Early flights proved that the operation of the automatic control was good at 30 in. Hg, but unsatisfactory when operating in the cruising position, as the carburetor pressure would surge two to four inches with a corresponding surge in engine manifold pressure.

The blower speed of the engine was such that at full throttle at sea level, without turbine boost, the engine developed full rated power. Experience thus far indicates such blower speed to be desirable for turbine supercharged installations as it permits use of an engine manifold pressure always higher than the carburetor pressure. Inasmuch as the exhaust back pressure, at rated power, varies from about 2 in. Hg above carburetor pressure at sea level, to two inches below carburetor pressure at 35,000 ft. it is desirable to maintain the engine manifold pressure at least 2 in. Hg higher than the exhaust back pressure to insure good scavenging. Use of lower blower speeds involving employment of turbine boost to secure rated power reverses this condition and results in a higher exhaust back pressure than engine manifold pressure.

In order to correct the carburetor pressure surging during high altitude cruising, the automatic pressure regulator was modified to permit the pilot to select any desired carburetor pressure from 20 to 30 in. Hg. Power control with this change was satisfactory and was accomplished as follows: On take-off, the automatic regulator control was set for "waste gate open" and climb was made using the throttle only to maintain desired cruising climb power. When full throttle was reached, critical altitude for the desired climbing power, the automatic regulator control was set so that the resulting carburetor pressure was sufficient to just maintain the desired engine manifold pressure. With controls so set, and the mixture set according to the Cambridge indicator, no further adjustment was necessary until cruising altitude was reached when the automatic control was readjusted to give the desired engine manifold pressure, slight mixture change was then necessary. Thus, above critical altitude of the engine for allowable cruising climb power (full throttle), engine control was wholly accomplished by means of the automatic regulator, the control of which became virtually a secondary throttle above critical altitude.

It appears, from experience, to be a sound principle in turbine supercharger operation to employ only the amount of turbine boost necessary to cause the desired engine manifold pressure. Thus, the exhaust turbine operates with the maximum waste gate opening and therefore minimum exhaust back pressure. It is this degree of control which constitutes one of the prime advantages of the turbine supercharger—its flexible coupling to the engine permitting under all conditions the minimum expenditure of available power for supercharging.

A factor which caused some concern during the earlier test flights was that of carburetor ice. It had been supposed that the temperature rise through the compressor would be adequate to eliminate this trouble. During descent from high levels, indications of carburetor ice were observed. In this connection it was noted that throttling back the engine resulted in rapid drop of carburetor pressure due to the inadequacy of exhaust gas to maintain the turbine speed. In fact, if the engine is completely throttled at about 30,000 ft. it is difficult to bring the engine back. The cause of this is obvious. Without turbine boost the engine power available is negligible and the amount of exhaust gas resulting at full throttle takes several minutes to bring the turbine up to speed. Also, it must be borne in mind that loss of turbine boost causes the carburetor to become excessively rich and considerable leaning is necessary to even make the engine run until the carburetor pressure begins to build up. If the engine is left throt-

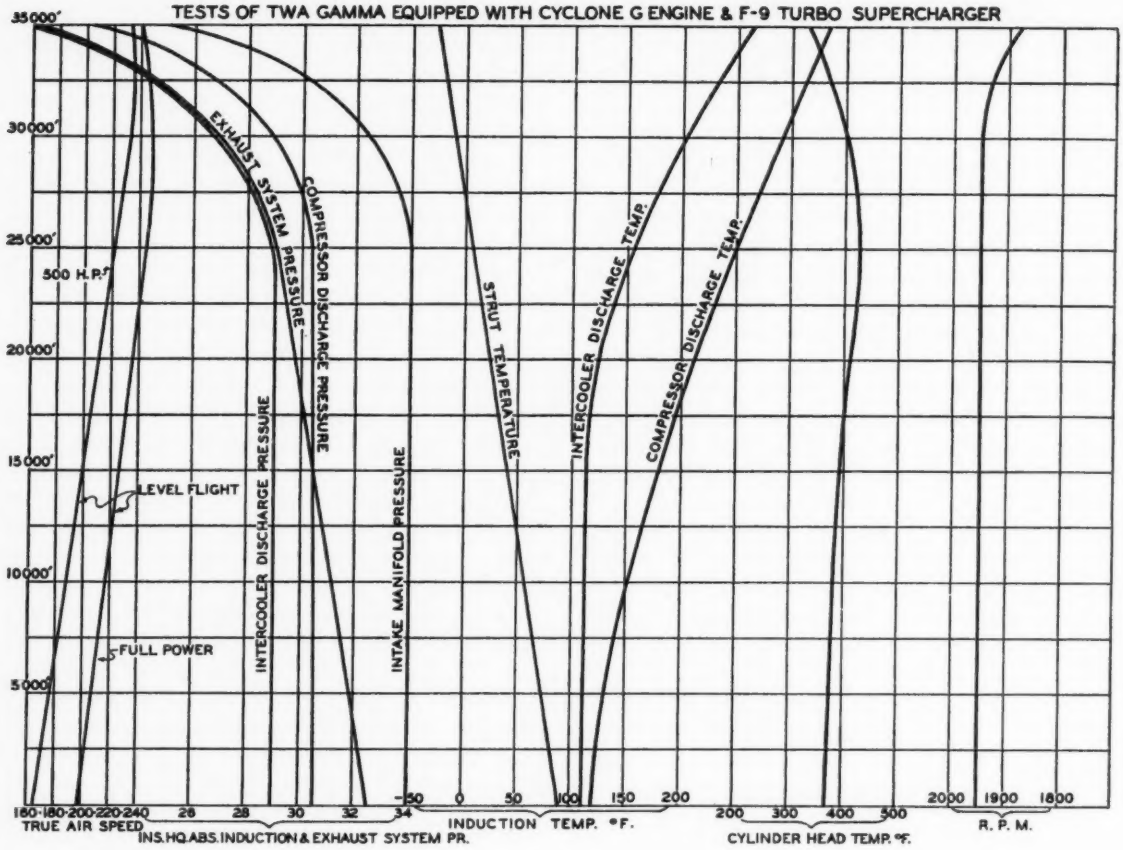


FIG. 1.

tled long enough to allow the turbine wheel to nearly stop rotating, it may be impossible to start it until the plane has descended to around 20,000 ft. Therefore, in making descents, sufficient power should be maintained to keep the turbine wheel turning fast enough to produce a constant carburetor pressure.

Considerable flying was done on instruments in ideal ice forming conditions. Although no indications of carburetor ice were observed during take-off and climbs, the carburetor adapter temperatures were frequently below 32°F. Therefore, shutters controllable from the cockpit were placed at the cooling air entrance to the intercooler. With these shutters closed, it was possible to keep adapter temperature over 32°F. and to permit a 40°F. range of control over the intercooler discharge temperature. It is possible that in addition to the shutters, it may be desirable in some installations to provide means for taking the air into the compressor from either outside or from the engine section at the control of the pilot.

Spark plug trouble, evidenced by engine roughness, was observed above 25,000 ft. During a series of test flights made in collaboration with the Army at Wright Field, plugs were removed, tested, and new ones installed prior to flights. It was conclusively determined that plugs were breaking down between 25,000 and 30,000 ft. under full power operation. Several sets of plugs operated satisfactorily for extended periods at cruising power above 30,000 ft. However, better spark plugs than any then available will be required to insure satisfactory operation and life at altitudes above 25,000 ft.

The right magneto was found to be dead after a climb to 35,500 ft. This failure was caused by the high tension circuit arcing across from the high tension outlet to the ground. The arcing had burned a groove into the coil insulator. This was the only magneto failure.

No difficulty of any kind was encountered from the shielded ignition harness.

The curves of Fig. 1 are based upon all the data recorded during the series of thirty-three flights. Above 30,000 ft., the data is not conclusive. However, the curves as extrapolated check reasonably well with the data obtained. Due to the large number of instruments to be observed and readings taken, the only practical means of recording simultaneous data was through the use of a Leica Camera. The camera was mounted just ahead of the pilot's instrument board and at a distance

from the observer's board so that the field of the lens just covered all instruments. A landing light bulb was installed on each side of the observer's cockpit. Both lights were operated together by a push-botton switch. The observer to take a reading leaned to one side, out of the way of the field of the camera, turned on the lights and operated the camera shutter by means of an extension device. Readings were thus taken at even 1000 ft. altitudes during climbs and periodically while cruising. The developed films were either read with a magnifying glass or projected on a screen.

### Levels Speeds at Altitude

The air speed meter was calibrated over a speed course 4.8862 miles in length which resulted in an accurate calibration. Two flights were made to 30,000 using full power to obtain maximum climb performance. Level speeds were then observed at 30, 25, 15, 20, 10, and 5000 ft. At each altitude the plane was flown level at rated power except at 30,000 ft. which is approximately 2000 ft. above the critical altitude of the turbine supercharger installation. The power was then reduced to 500 hp. estimated, 26 in. Hg engine manifold pressure, and 1800 r.p.m. The exactness of this power determination is only approximate, as no one has yet figured a way to determine the hp. at altitude of an engine equipped with a turbine supercharger on account of the unknown quantitative effect of exhaust back pressure on power. It is hoped that a torque meter reading hp. direct will soon be available for use with geared engines. Until such an instrument is available, the approximation of power using manifold pressure, carburetor air temperature, and r.p.m. will have to suffice. The airplane was maintained on steady level flight for three to five minutes before each speed reading.

A question had been raised regarding the reliability of air speed meter readings at high altitudes. In order to prove the accuracy of true air speeds reduced from indicated air speeds observed at 30,000 ft., the Gamma was flown around a triangular course. In order to navigate such a course with any degree of accuracy, it was necessary to choose turning points having Department of Commerce Radio Range Stations. Fortunately, the Radio Range Stations at Kansas City, Kirksville, and Columbia, Mo., provided an excellent course, the length of the legs being 128 miles, $78^1/_2$ miles, and $120^1/_2$ miles, respectively. In flying this course nearly six miles above the ground it was not possible to maintain a constant heading with allowance for drift so as to maintain an absolutely straight track. However, the occasional inaccuracies of not over 10° in compass heading were not enough to vitiate the results. The pilot's visibility from the cockpit of the Gamma is extremely poor so that flying at high altitudes is largely done by instruments. The Kansas City Radio Range was used as a point of departure and finish, with turns being made at Kirksville and Columbia when over the respective cones of silence. Reducing the average indicated air speed gave a true air speed for the circuit of 224 m.p.h. The timed ground speed for the three legs was 268 m.p.h., 215 m.p.h., and 171 m.p.h., respectively. Graphic solution using the ground speeds gives a true air speed of 222 m.p.h. and wind 52 m.p.h. from 263°. It is considered that this figure substantiates the reduced true air speed remarkably well, the difference of 2 m.p.h. may be easily accounted for by inaccurate flying. The approximate power used was 500 hp.

The level speed curve of true air speeds at 500 hp. shows 165 m.p.h. at sea level and 225 m.p.h. at 30,000 ft. This is an increase of 36.4 per cent which compares with a theorectical maximum of 38 per cent.

### Overweather

Two round trip flights were made from Kansas City to Wright Field, Dayton, Ohio and one non-stop flight from Kansas City to Princeton, N. J. The latter flight and one east-bound flight from Kansas City to Wright Field are significant.

On December 17, 1936, the Gamma departed from Kansas City with J. C. Hiestand, TWA, and Captain H. G. Armstrong, U. S. Army Medical Corps as observers. A cruising power climb was made on a course for Columbia, Mo. Four distinct layers of clouds were traversed. The first layer, broken in places, extended from 2000 ft. to 5000 ft. The second layer, likewise broken, was between 8000 ft. and 10,000 ft. The third layer, more nearly solid than the first two, was from 19,000 to 19,500 ft. The uppermost layer was a thin sheet of haze-like cirrus and lay at 28,000 ft. On this flight, as on previous ones, the moment the plane touched high cirrus clouds, heavy static was heard in the radio. This static was so loud, a high-pitched buzzing note, that radio beams were obliterated. About ten miles west of Columbia, the plane was stabilized at cruising power, 500 hp., at 30,000 ft. on top of the cloud formation which extended to the east as far as could be seen. The top of the upper level rose gradually to 30,000 ft. so that cruising altitude was raised to 31,000 ft., temperature −35°F. The average true air speed of the Gamma was calculated to be 225 m.p.h.

Toward the end of the flight the problem became one of locating Dayton, which had last reported a 1000 ft. ceiling. The unusual speed made it easily possible to overshoot the field. Descent was begun immediately after passing Indianapolis, entering the cloud at 30,000 ft. Viewed from above, this cloud looked like any other cloud. However, upon entering it the appearance of the cloud was like a moderate mist instead of the dense fog-like aspect of the normal cloud. Also the instant the plane touched the cloud, all radio reception was ended because of heavy static. Without the Wright Field radio beam, which was plainly audible above the cloud, all that could be done was to maintain an easterly heading. All previous experience the writer had had with high clouds was that they usually consisted of

layers a thousand feet or so in thickness. After descending to 18,000 ft., during which period the cloud formation was solid and unchanging, both in appearance and static effect, real concern was felt about overshooting Dayton. The plane was therefore put into a spiral. The bottom of the cloud formation was reached at 8000 ft.—22,000 ft. of absolutely continuous cloud!

The Gamma was now between layers and the Wright Field beam came in distinctly, with increasing volume as the plane was headed east, thus indicating that the plane was still west of Dayton. Approach to the Wright Field radio range was made at 3500 ft., just on top of the lower overcase. The Wright Field range station cone of silence was passed at 2:27 p.m.; four minutes later the plane landed at Wright Field.

This flight proved the existence of high velocity winds at the base of the stratosphere above storm conditions in the troposphere below. As yet there is no way of accurately forecasting these winds and absolutely nothing is known about wind condition over any period at these levels. All data resulting from high altitude sounding balloon runs observed by theodolite, or the drift of stratosphere balloons, loses significance when it is realized that such data perforce had to be taken during general pressure distributions and atmospheric conditions ideal for light winds. The knowledge of wind conditions vital to aircraft operations at the base of the stratosphere is when storm conditions at low levels make sounding balloon runs impossible. Perfection of the meteorograph and extensive data from actual flights over many storm conditions must be had before any comprehensive knowledge will be available of winds on top of storm areas.

The last flight from Kansas City proved by far to be the most interesting and significant. It was planned to fly the Gamma to New York. The flight was to be nonstop and overweather, if suitable conditions prevailed.

The weather experienced on this flight which ended at Princeton, N. J., completely altered the writer's opinion, shared by many others, that storm clouds (thunderheads excepted) did not extend above 30,000 ft. In all probability, the top of the storm extended to approximately 40,000 ft. and covered the area from the Mississippi River to beyond the Atlantic seaboard. The fact that clouds, such as those encountered, do extend to 40,000 ft. offers no handicap to high altitude flying provided planes are equipped with shielded antistatic radio antennas. Throughout this flight, the air above 30,000 ft. was smooth as glass excepting one slight bump, barely noticeable, at 36,000 ft.

The conditions were so unusual that the viewpoint of the meteorologist, preparing the Kansas City forecast for this flight is pertinent and worthwhile. He commented as follows:

"For this particular flight, it appears that the error concerning the top was a very grave one since it rendered your radio virtually useless. In the light of your experience, it is readily conceivable that the overcast could be solid to altitudes in excess of thirty thousand feet since prior to the advent of the low cloudiness, there existed a cirrus-stratus overcast which is typical of a warm front situation as three separate and distinct layers, aware, of course, that the lower layer, which usually consists of stratus produced by falling precipitation, will under given conditions merge with the intermediate layer. However, I must confess that I had never considered the merging of the two upper layers—it had never been important. However, I have learned from experience that the alto-stratus layer preceding a warm front is almost without exception underestimated by observers. This is especially true prior to the beginning of precipitation, after which the cloud base will lower in proportion to the intensity of the precipitation, the movement of the front and the character of the air mass being overrun.

"There is little to offer as an explanation of this error except to say that our knowledge of conditions above 20,000 ft. is too limited to permit of accurate forecasting. The top as forecast was based on observations of regular flights, reports of airplane observations, etc., under similar synoptic conditions as they come to our attention with existing data available.

"Concerning the winds, existing conditions at the time and subsequent developments make it inconceivable to me that the winds could have been beyond the limits of 225° and 270° between Kansas City and Pittsburgh *up to 20,000 ft.* Above this altitude we again come to a problem which is purely theoretical and one which might well lead to endless discussion among meteorologists. I personally believe that the wind around 30,000 ft. was near 270°, but I cannot substantiate this and I can readily see where they *might* have been from 270° to 315°.

"To summarize, it is easy to understand why the top of the overcast extended to such great height, but it is another thing to say *when* this will occur. This was a simple case of a solid, unstable, maritime air mass being lifted over the warm front surface. However, as is not infrequently the case and experience has proven, there sometimes exists above these maritime air mass outbreaks a dry and stable air mass which causes the high and intermediate cloud layers to be distinctly stratified, or even preclude the possibility of a cloud deck of any significance above 15 or 20,000 ft. The information to such altitudes as 30,000 ft. is never available and frequently in periods of bad weather such as the day in question, no airplane observations whatsoever are available.

"The same holds true of winds aloft. They are nearly never available above 20,000 ft. My reason for believing that the wind was 225° to 270° is the fact that such a solid, high, extensive overcast existed, which also lends weight to the conclusion that this was a very intense and unusual warm front condition. The term "Unusual" is used in respect to our meager information of the sub-stratosphere.

"The only way to improve forecasting for such altitudes is intensive research with the radio-meteorograph, by double theodolite balloon soundings and such other methods as can be devised."

It is proposed that our meager knowledge of conditions at the base of the stratosphere be expanded by the following means:

(1) Airplane weather observation flights be taken over by the Government. The U. S. Army Air Corps has equipment suitable for regular flights to 30,000 ft. There are now in service about fifty suitable airplanes equipped with turbine superchargers. These planes will soon be obsolete from the military standpoint, but are suitable and satisfactory for use in making high altitude weather flights. These planes should be made available for this purpose equipped with deicers and operated either by the Army or turned over to a special department of the Weather Bureau to be charged with this particular mission, which would or-

ganize a Government unit including pilots and mechanics to perform the flying.

(2) Establish a large number of meteorograph stations to augment the data obtained from airplane observations and to extend our knowledge of conditions into the stratosphere, say to 50,000 ft.

(3) Secure Congressional appropriation for the development of an experimental high altitude, high speed transcontinental air mail service using aircraft capable of cruising at 30,000 ft. and making not more than one stop. This scheduled operation will provide a proving ground for all the mechanical devices essential for high altitude flying, including pressure cabins, and will pave the way for the passenger transports.

Regular transport operation at 30,000 to 35,000 ft. levels will come within the next ten years. It will play an important part in long range, non-stop transcontinental and oceanic flying. The surface, so to speak, has hardly been tickled, let alone scratched. Enough has been done to clearly show how much there is to learn.

Government help is necessary to obtain vital data and to establish an experimental stratosphere service which will lead to the annihilation of great distances and make the world in fact a group of neighborly nations.

## Book Reviews

**The Aviation Industry,** by WM. BARCLAY HARDING; Chas. D. Barney & Co., New York, 1937; 74 pages, $2.50.

Every few years some banking company publishes a survey of the aircraft industry from the financial standpoint. Mr. Harding's conclusions are interesting because they are extremely conservative and do not create false hopes as to the future of aviation securities. In fact, the whole investigation appears to have been made in an impartial manner and from sources that are usually regarded as trustworthy.

Comparing the size of the aircraft industry with other large manufacturing groups gives a proper perspective owing to the amount of publicity aircraft secures in the newspapers. Few will criticize the conclusions as to the relative stability of the various groups that comprise the industry nor the well established fact that the government procurement forms the backbone of the sales. Recommending a short term viewpoint when purchasing aviation stock is sound advice which is diametrically opposite to much of the advice given for investment in similar stocks in the past.

Statistically the book gives a broad summary of the extent and growth of the component parts of the industry—manufacturing, air transport, export trade, and private flying. The close relationship of the government to all except the latter is clearly shown.

Less emphasis is placed on airport development and the accessory companies than would be expected in a book which bears such a broad title. The book was issued on an unfortunate date, December 1, 1937. Only the 1936 data is available in full and estimates had to be used for 1937. If the publishers will, as soon as the figures become available, issue a small supplementary booklet bringing the tables up to date they will render an added service. The text will need no revising as it takes into consideration the developments in 1937.

If more books of this kind were studied by investors there would be less grief over losses.

LESTER D. GARDNER

**Interavia ABC, 1937/1938;** Société Anonyme d'Éditions Aéronautiques Internationales, Switzerland, 1937; 1132 pages, $7.50.

The second edition of this invaluable reference book is a great credit to its editors. First issues of books which contain such a vast amount of data are always judged with understanding leniency. But the most critical searcher of this new guide to international aeronautical organizations can find only praise for its completeness and serviceability.

Not the least ingenious device used by the authors is their use of numbers on crowded maps to indicate places.

The aeronautical organization of practically every country is given with a completeness that makes the guide invaluable as a reference work.

In the United States section the various groups engaged in aviation activities are shown with personnel and location. Aeronautical Clubs and Societies, Schools, and all companies in the aircraft industry are listed with officers and useful addresses.

To assist readers who do not know German, French, Italian, and Spanish the principal aeronautical terminology in these languages is given in a glossary.

With the Aircraft Year Book, Jane's All the World's Aircraft, and Interavia ABC available, almost any information regarding the world's aviation organizations can be found.

# Notes on the Laminar Sub-Layer in Smooth Pipes

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## Introduction

IT IS generally believed that a laminar sub-layer always exists in the immediate vicinity of all solid boundaries of fluid flow systems. Although the thickness of this layer may be exceedingly small, it nevertheless plays an important role in the dissipation of mechanical energy by fluid friction, in heat transfer, and in explaining the distinction between hydraulically smooth and rough surfaces.

For any particular flow system, the thickness of the sub-layer would be expected to fluctuate with time and position along the boundaries due to eddies rolling up and leaving the laminar layer. However, in the following discussion an attempt will be made to derive an expression for a sort of average thickness with special reference to flow in smooth circular pipes, and to express the rate of energy dissipation within the sub-layer.

## Thickness of Laminar Layer

Since the flow in a circular pipe can be characterized by means of a Reynolds Number including the pipe diameter, the mean velocity, and the kinematic viscosity, it is reasonable to assume that flow in the laminar sub-layer is represented by an analogous criterion involving some characteristic length and velocity, and the viscosity of the layer. The velocity at the edge of the laminar layer and the layer thickness will be chosen as the characteristic velocity and length, respectively, giving for the local Reynolds Number of the layer, $u_\delta \delta \rho / \mu$.

Considering the layer thickness to be small as compared to the pipe diameter, the velocity gradient in the layer will be substantially linear and equal to $u_\delta/\delta$. Hence

$$\tau_0 = \mu \frac{u_\delta}{\delta} \text{ or } u_\delta = \frac{\tau_0 \delta}{\mu}$$

and the Reynolds Number of the sub-layer, $u_\delta \delta \rho / \mu$, can be written $\tau_0 \delta^2 / \rho \nu^2$. Bakhmeteff[1] has stated an equivalent criterion but did not determine its critical value. In the following analysis, a critical or characteristic value of $\tau_0 \delta^2 / \rho \nu^2$ will be determined for the laminar layer which is similar to the limiting Reynolds Number for laminar flow throughout the pipe.

The assumption will be made that the maximum value of $\tau y^2 / \rho \nu^2$ existing within a circular pipe at the critical value of $\bar{u} d \rho / \mu$, corresponds to the limiting value of $\tau_0 \delta^2 / \rho \nu^2$. For viscous flow in a pipe,

$$dp/dx = -8\mu\bar{u}/R^2$$

and

$$du/dy = -4\,\bar{u}\,(R - y)/R^2$$

Rembering that

$$\tau = -\mu(du/dy)$$

then

$$\tau = 4\mu\bar{u}\,(R - y)/R^2$$

and hence

$$\tau y^2/\rho\nu^2 = 2(\bar{u}d\rho/\mu)\,[(R - y)y^2/R^3] = 2Re[(R - y)y^2/R^3]$$

Differentiating the last term with respect to $y$ and equating to zero gives:

$$y = 2R/3$$

Hence:

$$\tau_0\delta^2/\rho\nu^2 = (\tau y^2/\rho\nu^2)_{max.} = 2Re[(2R/3)^2\,R - (2R/3)^3]/R^3$$

Taking the critical value of $Re$ as 2000 gives $\tau_0\delta^2/\rho\nu^2 = 590$

$$\delta = \sqrt{590}\;(\nu/\sqrt{\tau_0/\rho}) = 24.4\;(\nu/\sqrt{\tau_0/\rho})$$

Von Kármán[2] obtains for the thickness of the laminar layer, $\delta \doteq 11.5\,(\nu/\sqrt{\tau_0\rho})$ based on the position of the intersection of his generalized theoretical turbulent velocity distribution curve with the generalized viscous velocity curve. The experimental points on this same curve show a gradual deviation from the theoretical turbulent velocity curve at a distance $30(\nu/\sqrt{\tau_0/\rho})$ from the wall, and von Kármán refers to this as the reasonable upper limit of influence by laminar friction. The value, 30, would have been obtained above instead of 24.4 if a Reynolds Number of 3000 had been used rather than 2000 in the derivation of the critical value of $\tau_0\delta^2/\rho\nu^2$. The factor, 11.5, corresponds to a Reynolds Number of 450.

It seems plausible that the actual thickness of the laminar layer would be less than that obtained above for, after the flow in a pipe changes from laminar to the turbulent regime, there would be a disturbing effect of the turbulent core tending to disrupt the remaining laminar layer. Furthermore, for flat plates, the scale of turbulence outside the sub-layer would probably influence the critical value of $\tau_0\delta^2/\rho\nu^2$.[3] Then, too, mechanical disturbances such as vibration of the solid

boundary would undoubtedly affect the critical value as in the case of the overall pipe flow.

It is interesting to compare the critical value of the laminar sub-layer Reynolds Number obtained above with that for the break-down of the laminar regime between concentric rotating cylinders. Experiments described by G. I. Taylor[4] show that the break occurs for $ut/\nu = 1200$ to 1800 approximately, depending upon whether the outer or inner cylinder is held stationary while the other is rotated. Here, $u$, is the relative velocity of the two cylinders and, $t$, is the difference in their radii. At the instant just before the laminar state ceases, both the inner and outer cylinders have laminar layers of thickness $t/2$ with a maximum velocity relative to their respective solid boundaries equal to $u/2$ giving for the Reynolds Number for each layer $ut/4\nu = 300$ to 450 and indicating $17\ (\nu\sqrt{\tau_0/\rho}) \leq \delta \leq 21\ (\nu/\sqrt{\tau_0/\rho})$. This, at least, is in fair agreement with the value, 590, derived above based on flow in circular pipes.

### Energy Dissipation in Laminar Layer

A surprisingly large percentage of the total energy dissipation occurs within the laminar sub-layer, the ratio being equal to $u_\delta/\bar{u}$. The derivation is as follows: Designating the rate of energy dissipation per unit volume in the laminar layer by

$$E_\delta = \mu \left(\frac{\partial u}{\partial y}\right)^2 = \mu \left(\frac{u_\delta}{\delta}\right)^2$$

the power dissipated per unit of pipe length in the laminar layer is

$$P_\delta = 2\pi\ R\delta\mu \left(\frac{u_\delta}{\delta}\right)^2 = 2\pi R\mu\ \frac{u_\delta^2}{\delta}$$

The power dissipation for the entire pipe cross-section per unit length is

$$P_P = (dp/dx)\ \pi R^2\bar{u}$$

But

$$dp/dx = 2(\tau_0/R)$$

and

$$P_P = 2\pi R\tau_0\ \bar{u} = 2\pi R\mu(u_\delta/\delta)\ \bar{u}$$

Hence:

$$P_\delta/P_P = u_\delta/\bar{u}$$

This simple relationship is not mentioned in the literature so far as is known to the writer. It was called to the author's attention by M. P. O'Brien.

The ratio, $u_\delta/\bar{u}$, can be evaluated from the equation for the laminar layer thickness and Blasius' equation for the friction loss in smooth pipes. If von Kármán's value for the laminar thickness is substituted

$$\delta = 11.5\ (\nu/\sqrt{\tau_0/\rho})$$

but,

$$u_\delta = (\tau_0/\rho\nu)\delta$$

and

$$u_\delta = 11.5\sqrt{\tau_0/\rho}$$

Combining with the Blasius' equation gives

$$\tau_0 = (0.0393/\sqrt[4]{Re})\ \rho\bar{u}^2$$

$$u_\delta/\bar{u} = 2.28/\sqrt[8]{Re}$$

$$\delta = 58\ \sqrt[8]{Re}\ (\nu/\bar{u})$$

For example, if water at 76°F. flows through a smooth pipe at a velocity of 10 ft./sec., and a Reynolds Number of 50,000

$$u_\delta/\bar{u} = 0.59 \text{ and } \delta = 2.25 \times 10^{-4} \text{ ft.}$$

Thus, in this particular case about 60 per cent of the total dissipation takes place in a layer approximately the thickness of this sheet of paper. The dissipation per unit volume is

$$E_\delta = \mu(u_\delta/\delta)^2 = 13{,}000 \text{ ft. lbs./sec. ft.}^3$$

or

$$= 210 \text{ ft. lbs./sec. lb.}$$

which corresponds to a rate of temperature rise of 0.27°F./sec. The actual temperature increase in the layer would not continue at this rate because there would be an interchange of fluid between it and the central core as eddies form and leave. Furthermore, thermal conduction from the layer to the solid boundary and to the turbulent fluid would reduce the actual temperature rise in the layer.

### Symbols

| | | |
|---|---|---|
| $u$ | = | velocity at distance $y$ from solid boundary |
| $u_\delta$ | = | maximum velocity in laminar layer |
| $\bar{u}$ | = | average velocity over pipe cross-section |
| $\delta$ | = | thickness of laminar layer |
| $y$ | = | distance from solid boundary |
| $x$ | = | distance in direction of mean flow |
| $d$ | = | pipe diameter |
| $R$ | = | pipe radius |
| $r$ | = | radial distance |
| $\rho$ | = | fluid density |
| $\mu$ | = | coefficient of absolute viscosity |
| $\nu$ | = | coefficient of kinematic viscosity |
| $\tau$ | = | tractive force per unit area |
| $\tau_0$ | = | tractive force per unit area at solid boundary |
| $p$ | = | pressure |
| $E_\delta$ | = | energy dissipation per unit volume per second in laminar layer |
| $P_\delta$ | = | power dissipation in laminar layer per unit unit length of pipe |
| $P_P$ | = | power dissipation for entire cross-section per unit length of pipe |
| $Re$ | = | Reynolds Number $= \bar{u}d\rho/\mu$ |

### References


[1] Bakhmeteff, Boris A., *The Mechanics of Turbulent Flow*, p. 44, Princeton University Press, 1936.

[2] von Kármán, Th., *Turbulence and Skin Friction*, Journal of the Aeronautical Sciences, Vol. 2, No. 1, January, 1934.

[3] Taylor, G. I., *Effect of Turbulence on Boundary Layer*, Roy. Soc. London, Ser. A, V. 156, p. 307, 1936.

[4] Taylor, G. I., *Fluid Friction Between Rotating Cylinders*, Proc. Roy. Soc. London, Ser. A, V. 157, p. 546, 1936.

# Shear Distribution in a Sheet-Metal Box Spar

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## Summary

SIMPLE formulas for the shear distribution are given which can be applied to a sheet-metal box spar of any shape whatsoever, whether or not the skin contributes anything to the strength in bending. In addition, a simple graphical method for determining the shear center for such a box spar is given.


## Introduction

Within the last few years many airplane designers have become interested in the construction of wings in which the entire bending and torsion is carried by a single sheet-metal box spar. One great difficulty in designing such a spar has been the question of shear distribution along a cross-section. Hatcher,[1] in the April issue of this Journal, outlined a logical method for determining such a shear distribution. Unfortunately, he chose for his example a symmetrical rectangular box girder, which caused him to use mathematical concepts which could not be carried over directly to other types of box spars, particularly those in which the equations of the bounding curves are unknown. It is hoped that this paper will overcome this difficulty by providing simple formulas for the shear distribution in a box spar of any shape, whether or not any portion of the skin is effective in bending.

## Shear Distribution

It will be convenient to use Hatcher's concept of a sheet-metal box girder as being composed of a metal skin connecting one or more masses of metal (stiffeners), each of which is concentrated at a single point on the skin. This introduces a slight error by making it necessary to move either the skin or the stiffeners from their actual positions so that the center of gravity of each stiffener falls upon some point of the skin. However, the small error involved in so shifting the skin or stiffeners is compensated for by a greatly simplified process for finding the shear distribution in the spar.

It is assumed that the principal axes of inertia of the cross-section in question have been found and that the resultant shear force and moment have been broken up into components parallel to the principal axes (which are at right angles to each other). The $z$ axis is to be perpendicular to the plane of symmetry of the airplane; the $x$ and $y$ axes are perpendicular to the $z$ axis and pass through the principal axes of the cross-section

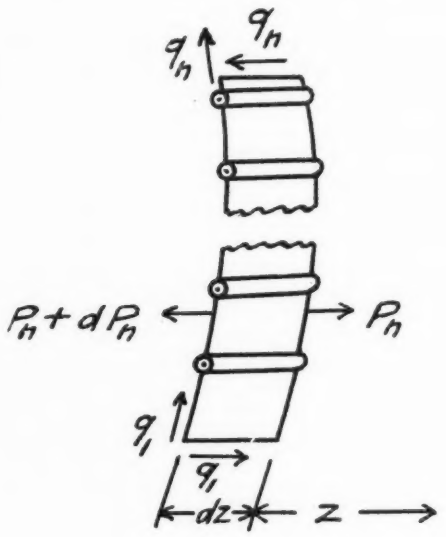


FIG. 1.

to be investigated. The discussion which follows applies to the moment and shear force associated with bending about the $x$ axis. An identical analysis with $x$ and $y$ interchanged applies to bending about the $y$ axis.

It is desirable to use a slightly different notation from that employed by Hatcher, namely,

$\tau$ = shear stress per unit area of skin.
$q$ = shear force per unit length of skin.
$t$ = thickness of skin.
$I$ = moment of inertia of the cross-section in question.
$F$ = shear force on the cross-section.
$Q$ = statical moment of an area about the $x$ axis.
$P$ = tensile or compressive force on an area.
$s$ = length (variable) of arc.
$L$ = length of arc between two specified points.
$k = L/t$.

Positive directions are to be as follows: counterclockwise for $q$ and $s$, upward for $F$ and tension for $P$.

The value of $q$ at any point on the perimeter can be expressed in terms of $q_1$, the value of $q$ at any desired starting point 1; $q_1$ can then be found by the principle of least work. It will be convenient to find values of $q$ at points which are an infinitesimal counterclockwise distance from each concentrated mass of metal. Thus, a series of arcs are dealt with, each of which has a concentrated mass located at its counterclockwise end.

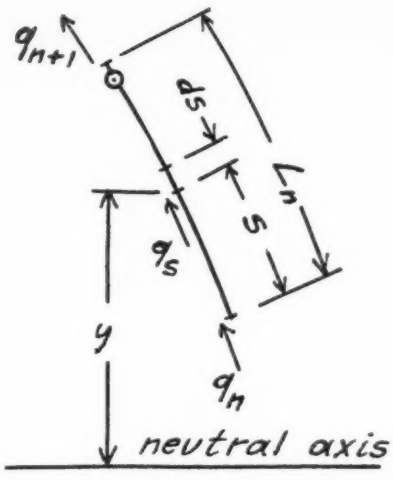


FIG. 2.

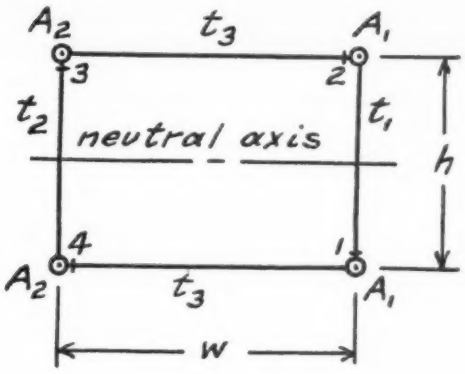


FIG. 3.

In Fig. 1 is shown a strip of skin of width $dz$ extending from point 1 to any point $n$ at an infinitesimal counterclockwise distance from one of the concentrated masses of metal. Note that on the upper end of this strip of skin, $q_n$ points to the left while on the lower end, $q_1$ points to the right. This is because the longitudinal and transverse shearing stresses at any point of a girder are equal and point either head to head or tail to tail. The result of taking summation of forces in the direction of $P_n$ is

$$q_n dz + P_n + dP_n = q_1 dz + P_n$$

The result of cancelling the $P_n$'s and dividing by $dz$ is

$$q_n = q_1 - dP_n/dz$$

It is a well-known fact that $dP/dz = FQ/I$. Hence

$$q_n = q_1 - FQ_{1n}/I \tag{1}$$

in which $Q_{1n}$ is the statical moment about the neutral axis of the cross-sectional area between points 1 and $n$.

In Fig. 2 is shown the portion of the skin extending from point $n$ to point $n + 1$. The shear $q_s$ at any distance $s$ along the arc from point $n$ is found in a manner identical to that by which $q_n$ was obtained (Eq. (1)). Thus

$$q_s = q_n - FQ_{ns}/I \tag{2}$$

in which $Q_{ns}$ is the statical moment about the neutral axis of the cross-sectional area between points $n$ and $s$. The result of combining Eqs. (1) and (2) is

$$q_s = q_1 - F(Q_{1n} + Q_{ns})/I \tag{3}$$

Now that the shear $q_s$ at any point $s$ has been expressed in terms of $q_1$, $q_1$ itself can be found by the principle of least work. In applying this principle, the work of shear in the stiffeners can be neglected, because such work is very small compared with the work done in the skin. The work done in the skin is

$$W = \Sigma W_n \tag{4}$$

in which $W_n$ is the work done in any arc of length $L_n$ (Fig. 2). It can be shown that

$$W_n = \int_0^{L_n} \tau_s^2 t_n ds/(2G_n) \tag{5}$$

in which $G_n$ is the shear modulus of elasticity for arc $L_n$. Since $\tau_s = q_s/t_n$, $W_n$ can be written in the form,

$$W_n = \int_0^{L_n} q_s^2 ds/(2G_n t_n) \tag{6}$$

The principle of least work requires that $\partial W/\partial q_1 = 0$. From Eq. (3), $\partial q_s/\partial q_1 = 1$ and hence

$$\partial W_n/\partial q_1 = \int_0^{L_n} q_s ds/(G_n t_n) \tag{7}$$

By virtue of Eq. (3), Eq. (7) becomes

$$\partial W_n/\partial q_1 = [k_n q_1 - F(k_n Q_{1n} + J_n)/I]/G_n \tag{8}$$

in which $k_n = L_n/t_n$ and

$$J_n = \int_0^{L_n} Q_{ns} ds/t_n \tag{9}$$

Since $W = \Sigma W_n$, the condition $\partial W/\partial q_1 = 0$ reduces to $\Sigma \partial W_n/\partial q_1 = 0$. By means of Eq. (8), this latter condition yields the following value of $q_1$:

$$q_1 = (F/I)[\Sigma(k_n Q_{1n}/G_n) + \Sigma(J_n/G_n)]/\Sigma(k_n/G_n) \tag{10}$$

If the entire skin is of the same material, $G_n$ is the same for all the arcs and hence

$$q_1 = (F/I)[\Sigma(k_n Q_{1n}) + \Sigma J_n]/\Sigma k_n \tag{11}$$

It will be convenient to know $J$ for a straight line of length $L$ inclined at any angle whatsoever to the $x$ axis. If $a$ and $b$ are the values of $y$ at the clockwise and counterclockwise ends of this line, respectively, Eq. (9) reduces to

$$J = L^2(2a + b)/6 \tag{12}$$

It will be interesting to apply the formulas so far developed to the box girder treated by Hatcher,

namely, the one shown in Fig. 3. The skin of this box girder is to be of the same material throughout.

### *Case 1. Skin ineffective in bending*

Each $J = 0$ because each $Q_{ns} = 0$ (Eq. (9)). From Figs. 1, 2, and 3, $k_1 = h/t_1$, $Q_{11} = 0$, $k_2 = w/t_3$, $Q_{12} = A_1h/2$, $k_3 = h/t_2$, $Q_{13} = (A_1 + A_2)h/2$, $k_4 = w/t_3$, $Q_{14} = A_1h/2$, $I = (A_1 + A_2)h^2/2$. When these quantities are substituted in Eq. (11), the resulting value of $q_1$ is $t_1$ times the value of $q_1$ given by Hatcher. This is a perfect check because the $q$ used in this article is $t$ times the $q$ used by him.

### *Case 2. Entire skin effective in bending*

The values of $k$ are the same as given in Case 1, but the $Q$'s must now include the statical moments of the skin; moreover, the $J$'s are not zero (Eq. (12)). Thus, $Q_{11} = 0$, $Q_{12} = A_1h/2$, $Q_{13} = (A_1 + A_2 + wt_3)h/2$, $Q_{14} = (A_1 + wt_3)h/2$, $J_1 = -h^3/12$, $J_2 = w^2h/4$, $J_3 = h^3/12$, $J_4 = -w^2h/4$. Let $q_0$ be the shear at a point midway between points 1 and 2. Then from Eq. (1)

$$q_0 = q_1 - FQ_{10}/I = q_1 + Fh^2t_1/(8I)$$

If the values of $k$, $Q$, and $J$ given above are substituted in Eq. (11) and the resulting value of $q_1$ introduced in this formula for $q_0$, it turns out that $q_0$ is $t_1$ times the value of $q_0$ given by Hatcher. This is a perfect check since the $q$ used in this article is $t$ times the $q$ used by him.

Cases 1 and 2 have illustrated the following facts concerning the $J$'s; namely, $J = 0$ for any arc in which the skin is ineffective in bending, and $\Sigma J_n = 0$ for a symmetrically shaped girder, regardless of the thickness of the skin in the various parts of the girder.

### Formulas for $Q$ and $J$ by Simpson's Rule

If box girders were always constructed of straight lines or arcs of circles, $J_n$ could be left in the form of Eq. (9). But for more complicated curves, and particularly for curves whose equations are unknown, $J_n$ must be put in a different form. This is accomplished by means of the following integration by parts:

$$J_n = \int_0^{L_n} Q_{ns}ds/t_n = [Q_{ns}s/t_n]_0^{L_n} - \int_0^{L_n} s\,dQ_{ns}/t_n \quad (13)$$

From Fig. 2,

$$Q_{ns} = \int_0^s y\,t_n ds \quad (14)$$

Hence

$$[Q_{ns}s/t_n]_0^{L_n} = (L_n/t_n)\int_0^{L_n} yt_n ds - (0/t_n)\int_0^0 yt_n ds = \int_0^{L_n} L_n y ds \quad (15)$$

Moreover, from Eq. (14), $dQ_{ns}/t_n = y\,ds$. By means of this relation and Eqs. (13) and (15),

$$J_n = \int_0^{L_n} L_n y ds - \int_0^{L_n} sy ds = \int_0^{L_n} (L_n - s)y ds \quad (16)$$

Values of $Q$ and $J$ for any arc of length $L$ can be found from Simpson's Rule, as follows. Divide the arc into $n$ equal parts ($n$ = an even integer) and label the $y$'s to the division points of the arc from 0 to $n$, beginning at the clockwise end. Simpson's Rule applied to Eq. (14) with $L$ substituted for $s$ gives the following value of $Q$:

$$Q = \frac{tL(y_0 + 4y_1 + 2y_2 + 4y_3 + \ldots + 4y_{n-1} + y_n)}{3n} \quad (17)$$

Formulas for $J$ are obtained by applying Simpson's Rule to Eq. (16). When length $L$ is divided into 4, 6, and 8 parts, the respective formulas for $J$ are:

$$J = L^2(y_0 + 3y_1 + y_2 + y_3)/12 \quad (18)$$

$$J = L^2(1.5y_0 + 5y_1 + 2y_2 + 3y_3 + y_4 + y_5)/27 \quad (19)$$

$$J = L^2(2y_0 + 7y_1 + 3y_2 + 5y_3 + 2y_4 + 3y_5 + y_6 + y_7)/48 \quad (20)$$

Consider a straight line of length $L$ inclined at any angle whatsoever to the $x$ axis, with $a$ and $b$ the values of $y$ at the clockwise and counterclockwise ends of the line, respectively. Note that $y_0 = a$, $y_1 = a + (b - a)/n$, $y_2 = a + 2(b - a)/n$, . . ., $y_{n-1} = a + (n - 1)(b - a)/n$, $y_n = b$. For any value of $n$, Eq. (17) reduces to the well known result $Q = tL(a + b)/2$. Moreover, Eqs. (18), (19), and (20) all yield the value of $J$ given in Eq. (12).

### Location of Shear Center

It is well known that the counterclockwise moment of the shear $q$ per unit length of arc about a point $O$ is

$$M = \int q\,r^2\,d\theta \quad (21)$$

in which $\theta$ is measured in radians and $r$ is a radius vector from point $O$ to any point on the skin, with both $\theta$ and $q$ positive when counterclockwise. By means of this formula a graphical method for obtaining $M$ can be found, as follows. For a number of points on the skin find the shear $q$ and the radius $r$. From point $O$ lay off a new radius vector $R = r\sqrt{(q/q_1)}$ in the direction of the original radius vector $r$—there will be two radii of different length at each concentrated mass of metal (Fig. 4). Through the outer ends of radii $R$ draw a smooth curve (Fig. 4) and find its area $A_R$ by means of a planimeter. Note that

$$A_R = \int R^2 d\theta/2 = \int q\,r^2\,d\theta/(2q_1) = M/(2q_1) \quad (22)$$

Hence

$$M = 2q_1A_R \quad (23)$$

It should be borne in mind that wherever $q/q_1$ is negative, the corresponding area must be taken as negative and hence it must be added algebraically to the positive

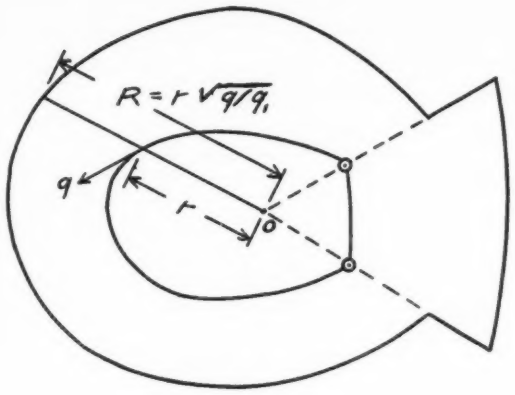


FIG 4.

areas. This can be accomplished without first finding the positive and negative areas separately if the planimeter is traced in a counterclockwise direction around positive areas and in a clockwise direction around negative areas.

The distance $x_c$ from the center of moments $O$ to the shear center $C$ is found from the relation

$$x_C = M/F \tag{24}$$

in which a positive value of $x_C$ indicates that $C$ is to the right of $O$, which follows from the fact that $M$ is positive when counterclockwise and $F$ is positive when upward.

It will be interesting to apply this graphical method to a box spar which can be easily checked analytically.

*Example.* Fig. 5 shows a rectangular box spar with skin ineffective in bending; hence $q$ is constant between concentrated masses of metal. If the center of moments $O$ is at the center of the rectangle, the moment $M$ is

$$M = 10 \times 4 \times 3 + 20 \times 6 \times 2 - 60 \times 4 \times 3 + 20 \times 6 \times 2$$
$$= -120 \text{ in. lbs. (clockwise)}$$

Since $F = 10 \times 4 + 60 \times 4 = 280$ lbs.

$$x_C = -120/280 = -3/7 \text{ in.}$$

Hence $C$ is 3/7 inch to the left of $O$.

For the graphical method, let $q_1 = 10$ lbs. /in. in a counterclockwise direction. Area $A_R$ is then as shown in Fig. 6. Note that the left triangular area is negative

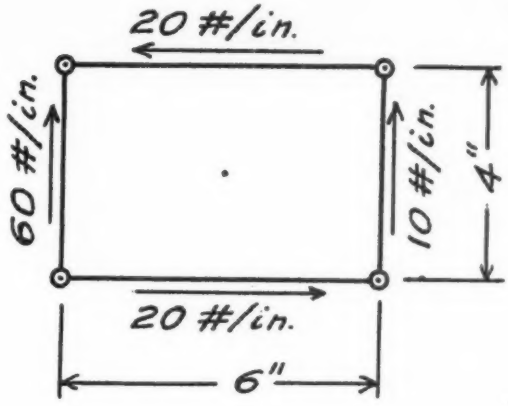


FIG. 5.

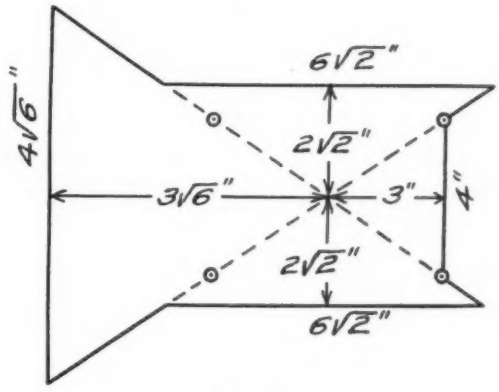


FIG. 6.

because the 60 lbs./in. shear is clockwise; the other three triangular areas are positive because their corresponding shears are counterclockwise. Hence

$$A_R = (3 \times 4 + 2\sqrt{2} \times 6\sqrt{2} - 3\sqrt{6} \times 4\sqrt{6} + 2\sqrt{2} \times 6\sqrt{2})/2 = -6 \text{ sq. in.}$$

Then from Eq. (24),

$$M = 2 \text{ (10 lbs./in.) } (-6 \text{ sq.in.}) = -120 \text{ in. lbs.}$$

which checks the value of $M$ obtained analytically.

REFERENCE

[1] Hatcher, Robert S., *Rational Shear Analysis of Box Girders*, Journal of the Aeronautical Sciences, Vol. 4, No. 6, pp. 233–238, April, 1937.

# A Simple Method for Determining the Aerodynamic Center of an Airfoil

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(Received November 29, 1937)


## Summary

THIS paper presents in analytical form a method for locating exactly the aerodynamic center of an airfoil, this point being that about which the moment is constant for the usual range of angles of attack. An illustration is given showing the application of the method to a Clark Y airfoil based on a wind-tunnel test in the University of Michigan wind tunnel.


## Introduction

In presenting experimental data on the aerodynamic characteristics of airfoils, it is now generally accepted practice to refer the pitching moment coefficients to the aerodynamic center of the airfoil section. This point is defined as that about which the moment coefficient is constant throughout the range of angles of attack corresponding to the linear part of the lift curve. This paper presents a simple method for locating exactly the aerodynamic center of an airfoil directly from wind-tunnel test data, all that is required being the lift and drag characteristics and the moment of the air reaction referred to some known point.

## Elementary Theoretical Considerations

Airfoil section theory[1] for thin sections of small camber shows that the moment and lift coefficients $C_m$ and $C_L$, respectively, are related by the equation

$$C_m = C_{m_0} - n\,C_L \tag{1}$$

where $C_m$ is referred to the leading edge of the section. The quantity $C_{m_0}$ represents the value of $C_m$ at zero lift or the initial moment coefficient and is constant for a particular airfoil. The term $n$ is theoretically constant for all airfoils and equal to 0.25. This theory neglects the drag force on the airfoil, assumes that the angle of attack is small and that the lift coefficient is a linear function of the angle of attack. Retaining these assumptions it may easily be shown that the moment coefficient referred to any point on the chord line at a distance $x_0$ from the leading edge is

$$C_m' = C_{m_0} - [n - (x_0/c)]\,C_L \tag{2}$$

where $c$ is the chord. Thus if $x_0/c = n$, $C_m' = C_{m_0}$ and is constant. Hence $x_0/c = n$ gives the location of the aerodynamic center as a fraction of the chord based on the approximate airfoil theory. If $n = 0.25$, the aerodynamic center is at the quarter-chord point.

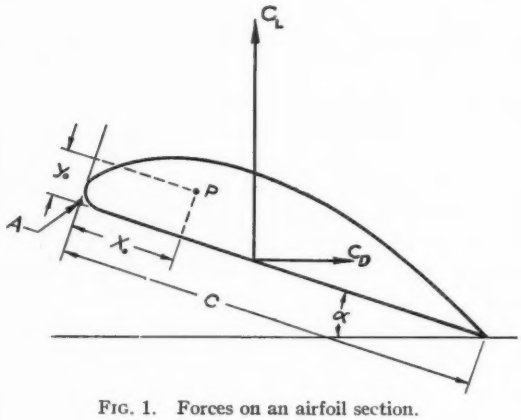


Fig. 1. Forces on an airfoil section.

## Exact Method

In practice it is found that the aerodynamic center is usually slightly forward of the quarter-chord point, and also a small distance off the chord line. These deviations are due to the fact that $n$ in Eq. (1) is somewhat less than the theoretical value of 0.25 and that the drag has been neglected.

Elementary mechanics may be used to derive an exact relation between the lift, drag, and moment coefficients for a given angle of attack. In Fig. 1 is shown a section of an airfoil at an angle of attack $\alpha$, with the lift and drag forces acting on it represented by the corresponding coefficients, $C_L$ and $C_D$. The moment about the leading edge $A$ is assumed to be known and is represented by the coefficient $C_m$.

The moment coefficient referred to any other point such as $P$ is

$$C_m' = C_m + (x_0/c)\,(C_L\cos\alpha + C_D\sin\alpha) - (y_0/c)\,(C_D\cos\alpha - C_L\sin\alpha) \tag{3}$$

where $x_0$ and $y_0$ represent the coordinates of $P$ referred to $A$ as an origin and measured parallel and perpendicular to the chord, respectively. If $P$ is the aerodynamic center, then $dC_m'/dC_L = 0$. This condition leads to the following relation:

$$\frac{x_0}{c}\left[\left(\frac{dC_D}{dC_L} - C_L\frac{d\alpha}{dC_L}\right)\sin\alpha + \left(1 + C_D\frac{d\alpha}{dC_L}\right)\cos\alpha\right] + \frac{y_0}{c}\left[\left(1 + C_D\frac{d\alpha}{dC_L}\right)\sin\alpha - \left(\frac{dC_D}{dC_L} - C_L\frac{d\alpha}{dC_L}\right)\cos\alpha\right] = -\frac{dC_m}{dC_L} \tag{4a}$$

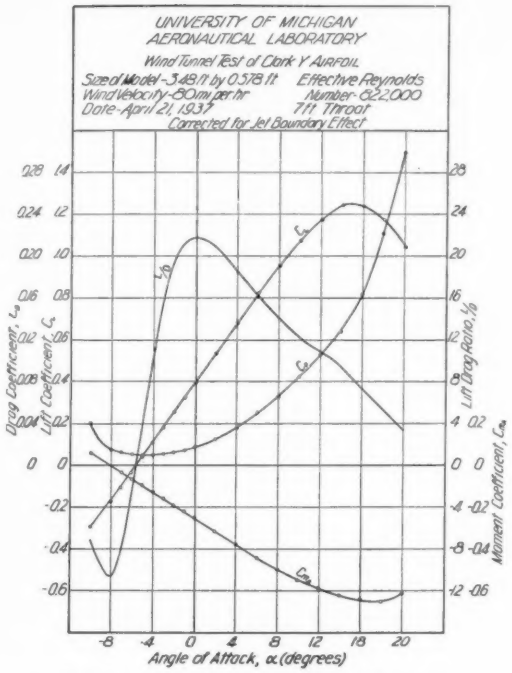
UNIVERSITY OF MICHIGAN
AERONAUTICAL LABORATORY
Wind Tunnel Test of Clark Y Airfoil
Size of Model - 3.48 ft by 0.578 ft
Wind Velocity - 80 m. per hr
Date - April 21, 1937
Effective Reynolds Number - 822,000
7 ft Throat
Corrected for Jet Boundary Effect
Drag Coefficient, $C_D$
Lift Coefficient, $C_L$
Lift-Drag Ratio, L/D
Moment Coefficient, $C_m$
Angle of Attack, α (degrees)

FIG. 2. Test results for the Clark Y airfoil.

For simplicity the terms in the brackets may be represented by $E$ and $F$, respectively, so that

$$E\,(x_0/c) + F\,(y_0/c) = -\,dC_m/dC_L \qquad (4b)$$

The terms $E$ and $F$ for a given value of $\alpha$ may be evaluated from the wind-tunnel test data available along with the value of $dC_m/dC_L$. Inasmuch as there are two unknowns, $x_0$ and $y_0$, to be determined, two equations are required. These may be obtained by considering values of $E$ and $F$ for any two angles of attack corresponding to the linear portion of the lift curve, in which range $dC_m/dC_L$ is generally constant. If $dC_m/dC_L$ is not constant its variation is readily incorporated in Eq. (4b).

It should be pointed out that this analysis is not restricted to cases where $C_m$ is referred to the leading edge. The point $A$ may be located in any position whatsoever, provided only that $x_0$ and $y_0$ are the coordinates of $P$ referred to $A$ as origin. Thus the method may be applied to earlier airfoil data where $C_m$ is usually referred to the leading edge. It also may be applied directly to wind-tunnel data where the moment is measured about some point peculiar to the balance arrangement and of no particular significance with respect to the airfoil section.

### Example Using the Exact Method

The use of the method will now be illustrated by an example of a wind-tunnel test on a Clark Y airfoil made in the University of Michigan aeronautical laboratory. This airfoil model was carefully machined from an aluminum casting, polished, and finished with several coats of pigmented dope. It had a rectangular planform of 3.48 ft. span and 0.578 ft. chord. The test was conducted at a wind speed equivalent to 80 m.p.h. in air of the standard density of 0.002378 slugs/cu.ft. The lift, drag, and moment coefficients as obtained from the test but corrected for jet boundary effect are shown in Fig. 2, plotted against $\alpha$. The curve of the lift-drag ratio is also drawn in this figure. In this case the point $A$ is the hinge point forward of the leading edge used in supporting the model in the wire balance during the test.

TABLE 1

Comparison of N.A.C.A. and Michigan Test Results for Clark Y Wing

| Item | N.A.C.A. | Michigan |
|---|---|---|
| $C_{L_{max.}}$ | 1.21 | 1.255 |
| $\alpha_{L_0}$ | −6.3° | −5.58 |
| $dC_L/d\alpha$ per degree | 0.0708 | 0.0714 |
| $C_{D_0}$ at $C_L = 0$ | 0.0098 | 0.0102 |
| $C_{m_0}$ | −0.0691 to −0.0735 (Extrapolated) | −0.0752 |
| $(L/D)_{max.}$ | 20.3 to 22.8 (Extrapolated) | 21.75 |

Inasmuch as this airfoil was constructed to serve as a "standard" model for the wind tunnel and to check a number of changes in the balance arrangement made by the author, it may be of interest to compare some of the principal results with those obtained in other laboratories. Table 1 shows a comparison with tests made in the National Advisory Committee for Aeronautics full-scale wind tunnel.[2]

The actual Reynolds Number of the present test was 433,000 but in making this comparison an effective Reynolds Number of 822,000 was employed. This latter value was obtained by multiplying the actual value by a turbulence factor of 1.9, based on sphere drag tests and the work of the National Advisory Committee for Aeronautics correlating sphere drag and turbulence.[3] In the case of the drag coefficient at zero lift, this required the subtraction of a decrement of 0.0006 from the test value to take care of the change in skin friction in passing from the test to the effective Reynolds Number.[4] It appears that with the possible exception of the zero lift angle, the agreement of the present test values with the N.A.C.A. data is remarkably good.

Returning now to the calculation of the aerodynamic center coordinates using Eq. (4b), it is necessary to evaluate $E$ and $F$ for two values of $\alpha$. The choice of these angles is entirely arbitrary but in the present work the points chosen were those corresponding to minimum drag and maximum lift-drag ratio. The first point has the advantage that $dC_D/dC_L = 0$, while for the second, $dC_D/dC_L = 1/(C_L/C_D)_{max.}$. The angle of zero lift

TABLE 2

Evaluation of Constants for Aerodynamic Center Determination

| Item | At $C_{D\,min.}$ | At $(L/D)_{max.}$ |
|---|---|---|
| $\alpha$ | −5.00 | 0 |
| $C_L$ | 0.076 | 0.398 |
| $C_D$ | 0.0104 | 0.0183 |
| $dC_L/d\alpha$ per radian | 4.09 | 4.09 |
| $dC_D/dC_L$ | 0 | 0.0460 |
| $E$ | 1.000 | 1.005 |
| $F$ | −0.0689 | 0.0513 |
| $dC_m/dC_L$ | −0.441 | −0.441 |

might also be conveniently used instead of one of the above, and of course would be a logical choice if $C_{D_{min.}}$ occurs at zero lift. The information necessary to evaluate the coefficients $E$ and $F$ is contained in Table 2.

The two equations obtained by introducing these values of $E$ and $F$ in Eq. (4b) are thus

$$(x_0/c) - 0.0689\,(y_0/c) = 0.441$$

$$1.005\,(x_0/c) + 0.0513\,(y_0/c) = 0.441$$

Their simultaneous solution yields the values

$$x_0/c = 0.440;\ y_0/c = -0.02$$

Inasmuch as the point $A$ was located at a distance of 0.116 ft. ahead of and 0.0247 ft. above the leading edge, the coordinates of the aerodynamic center referred to the leading edge are

$$x_0'/c = 0.239;\ y_0'/c = 0.02$$

It is possible that the choice of other values of $\alpha$ than those used here would lead to slightly different values of $E$ and $F$ and therefore to slight modifications in the values of $x_0'/c$ and $y_0'/c$. However, it is believed that the results here obtained are a reasonable average for the linear portion of the lift curve.

The introduction of these values of $x_0/c$ and $y_0/c$ in Eq. (3) makes it possible to determine the moment coefficient referred to the aerodynamic center. For this purpose it is convenient to introduce the polar coordinates

$$K/c = \sqrt{(x_0/c)^2 + (y_0/c)^2}$$

$$\phi = \tan^{-1}\,(y_0/c)/(x_0/c)$$

in which case Eq. (3) takes the form

$$C_m' = C_m + (K/c)\,[C_L \cos\,(\alpha - \phi) + C_D \sin\,(\alpha - \phi)] \quad (5)$$

which is slightly better adapted to computations than Eq. (3). The values of $C_{m\,a.c.} = C_m'$, along with those

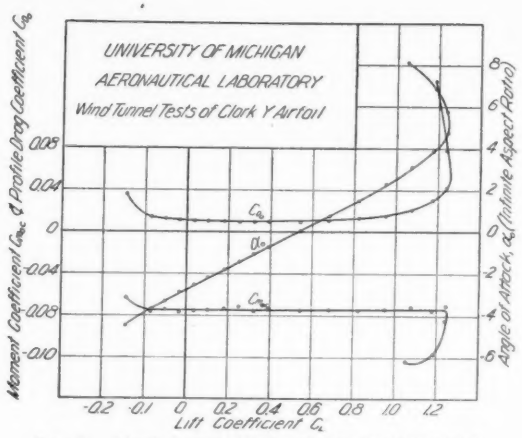


FIG. 3. Final characteristics of the Clark Y airfoil.

of $C_{D_0}$ and $\alpha_0$ for infinite aspect ratio, are plotted against $C_L$ in the usual manner in Fig. 3. These results clearly verify the fact that the selected point results in a constant moment coefficient throughout the linear portion of the lift curve.

It is apparent in this example, at least, that a sufficiently accurate value of $x_0/c$ could have been obtained by putting $x_0/c = -dC_m/dC_L = 0.441$. This is equivalent to using the relation $x_0/c = n$, derived from Eq. (2). However, an examination of the values of the coefficients $E$ and $F$ of Eq. (4b) shows that they are very similar in form. In fact if $y_0/c$ is to be computed, there is very little additional labor entailed in employing the exact equation for $x_0/c$.

Attention should also be called to the fact that this method does not permit the determination of $y_0/c$ or $y_0'/c$ to a large number of significant figures unless the original test data is sufficiently accurate to give the values of $E$ and $F$ to an unusually large number of significant figures. In fact, in the present example with $x_0/c$ determined as 0.440, $y_0/c$ could lie between 0.008 and 0.021 and still give $dC_m'/dC_L = 0$ to three places to the right of the decimal point. It therefore appears that with usual wind-tunnel test data, it would be justifiable to give the ordinate of the areodynamic center to only one or two significant figures.

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[1] Glauert, H., *The Elements of Aerofoil and Airscrew Theory*, p. 91, Cambridge University Press, Cambridge, 1926.

[2] Silverstein, Abe, *Scale Effect on Clark Y Airfoil Characteristics from N.A.C.A. Full-Scale Wind-Tunnel Tests*, N.A.C.A. Tech. Report No. 502, Washington, D. C., 1934.

[3] Platt, Robert C., *Turbulence Factors of N.A.C.A. Wind Tunnels as Determined by Sphere Tests*, N.A.C.A. Tech. Report No. 558, Washington, D. C., 1936.

[4] Jacobs, Eastman N., and Sherman, Albert, *Airfoil Section Characteristics as Affected by Variations of the Reynolds Number*, N.A.C.A. Tech. Report No. 576, Washington, D. C., 1937.

# Wind-Tunnel Tests on a Low Wing Monoplane with Propellers Running: Longitudinal and Directional Stability, Elevator Hinge Moments

S. S. Miller and W. H. Albach, *U. S. N. and California Institute of Technology**

(Received November 6, 1937)

## Introduction

VARIOUS tests have been conducted on airplane wind-tunnel models with an operating propeller in an endeavor to furnish data for use in design and performance predictions. At the GALCIT† these investigations have comprised the material set forth in references 1, 2, and 3.

The tests conducted by the authors of this paper represent a continuation of the above-mentioned investigations. The purposes of the present tests were to determine (1) the effect of power on static longitudinal stability (elevator free), (2) the effect of power on elevator hinge moments (at various tab angles), and (3) the effect of power on static directional stability with the model operating at high and low angle of attack.

## Description of Model

The model used was the same as that employed by Bolster.[3] Fig. 1 shows three views of the model which is that of a typical low-wing, single-engine, tractor monoplane to one-sixth scale. Although the results of the present tests are most directly applicable to airplanes of the model's general design, the effects are considered to show qualitatively what may be expected, in general, in multiple-engine, tractor monoplanes of present-day design.

Since the linear velocities of the blade elements of the propeller on the model equaled the linear velocities of the full-scale propeller, and power was approximately $^1/_{36}$ of full-scale power ($^{432}/_{36}$ = 12 hp.), the slipstream effects should closely simulate those encountered at full scale.

## Description of Apparatus

In the tests dealing with static longitudinal stability, the desired tab angle was set with elevator free and the run started. Power was varied in accordance with a predetermined schedule, and air velocity, geometrical angle of attack, lift, resultant drag, and pitching moment were measured in the normal manner.[4]

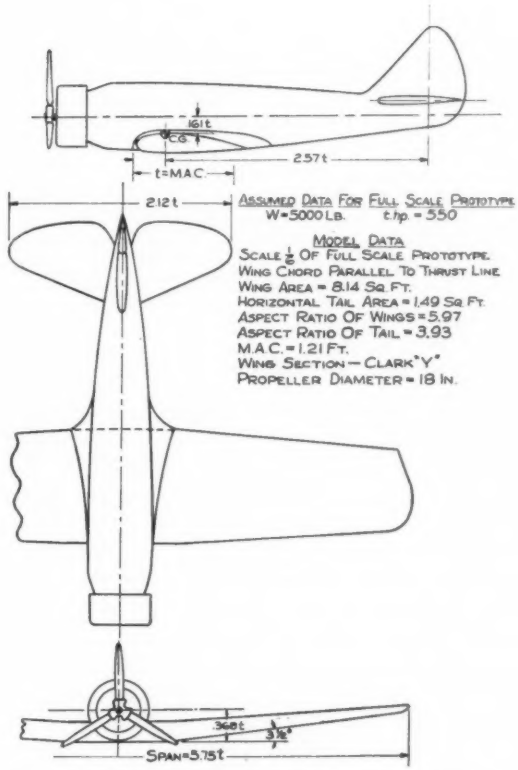


FIG. 1. Three-view of model with driven propeller.

Elevator hinge moments were obtained directly by means of a simple mechanical rigging, and elevator angles were read visually at the same time.

In determining yawing moments the model was mounted in the tunnel so that the yawing moment was read via the pitching moment balance. For this portion of the investigation, the elevator was locked at zero position and the tabs were set at zero angle. During the test the rudder was varied throughout a range of 25° on either side of the neutral position in increments of 5°. No tests were attempted with rudder free.

Fig. 2 shows the tail surface shapes and dimensions. The elevators were statically, and partially aerodynamically, balanced.

* The authors wish to express their gratitude to the GALCIT wind-tunnel staff for its cooperation in the elaborate testing procedure, to C. M. Bolster for his assistance in the early portion of the investigation, and to Clark B. Millikan for his general supervision of the whole project and his many helpful suggestions.

† Guggenheim Aeronautics Laboratory, California Institute of Technology.

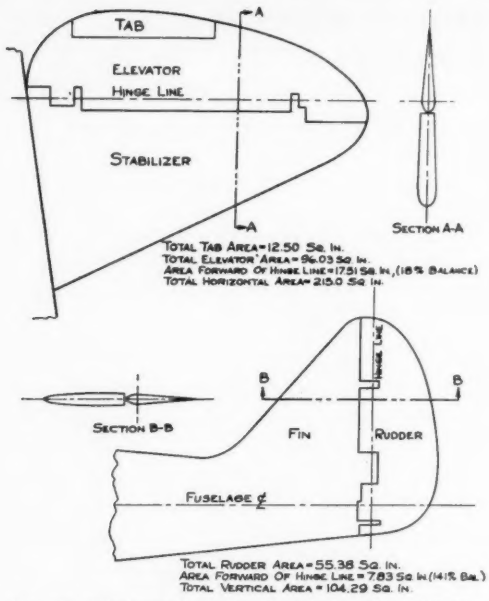


FIG. 2. Horizontal and vertical tail surface dimensions.

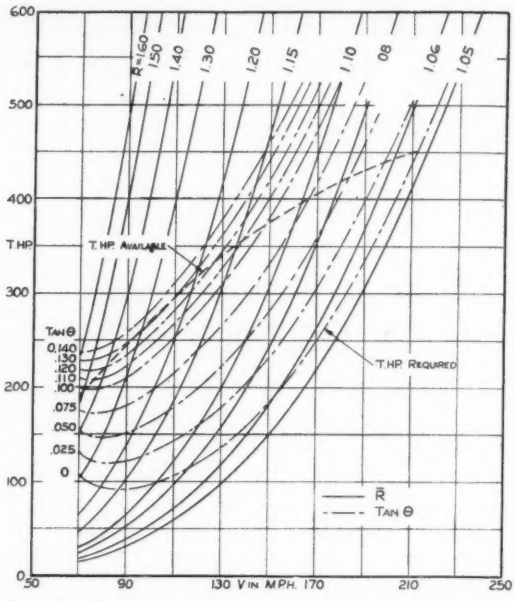


FIG. 3. Thrust horsepower and power parameters for full-scale prototype of the model.

## METHODS OF MEASURING POWER

The power parameter, tan $\theta$, was employed in connection with that portion of the experiment dealing with the effect of power on static longitudinal stability (elevator free). $\theta$ is the angle of climb of the model's full-scale prototype, the derivation of this parameter being given in reference 1.

Another power parameter, designated as $\overline{R}$, was employed in connection with that portion of the tests dealing with the effect of power on hinge moments (elevator free), and the effect of power on static directional stability. This power parameter was employed in preference to tan $\theta$ in this portion of the tests, because no accurate means was available to determine the resultant drag coefficient with the type of rigging employed. $\overline{R}$ is defined as the ratio $V(slipstream)/V(infinity)$. Therefore,

$$\overline{R} = \left(\frac{8}{\pi} T_c + 1\right)^{1/2}$$

(see Weick, *Aircraft Propeller Design*)

$\overline{R}$ will, of course, vary slightly with the angle of inclination of the thrust line to the direction of undisturbed airflow. Experimental results show that, within the limits of accuracy, the error introduced by inclination angles up to 30° is negligible.

## RANGE OF POWER

The range of power was sufficient to cover the flying range for an airplane of a type similar to that of the model. The method of determining this range was identical to that outlined in reference 1.

The relation between the two power parameters is shown in Fig. 3 where are plotted t.hp. against velocity for constant values of $\overline{R}$ and tan $\theta$. The tan $\theta = 0$ curve is obviously the customary power-required curve for level flight.

## STATIC LONGITUDINAL STABILITY (ELEVATOR FREE)

The curves showing the effect of power on static longitudinal stability (elevator free) are given in Fig. 4. A separate family of curves is drawn for each tab angle. Each family of curves shows the effects of power ranging from tan $\theta = -0.05$ to $+0.15$.

The effect of power on static longitudinal stability for tab angles of $+20°$ and $+30°$ was investigated but showed such small variations from the effects noted for $+10°$ tab angle, that the curves for the former angles are not included in this report. It is felt that the most effective tab angle probably lies between $+10°$ and $+20°$, but this cannot be stated with certainty since no investigation was conducted within this range.

The singular, wavy nature of the "power-on" curves is explained as follows: Let $C_{M_t}$ ($C_M$ due to tail) be plotted against $C_L$ for various fixed elevator angles. There is then a family of parallel lines of negative slope, each line corresponding to a certain fixed elevator angle. Now for a single tab angle setting, with elevator free, as $C_L$ varies, the elevator angle assumes various values due to interference, slipstream, variation in $\alpha$, and downwash. These various values of elevator angle, in conjunction with their corresponding $C_L$'s as arguments, allow the plotting of a curve which, with increasing $C_L$, jumps from one fixed elevator line to another. Thus a wavy $C_{M_t}$ *vs.* $C_L$ curve is obtained.

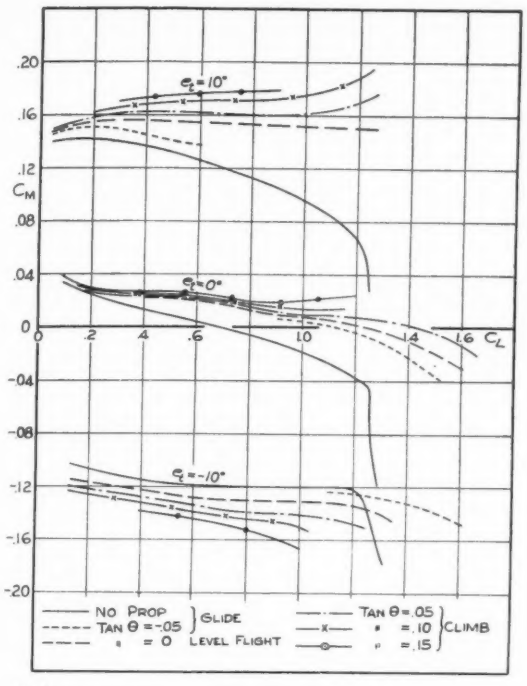


Fig 4

FIG. 4. Pitching moments with elevator free. $e_t$ = elevator tab angle (+ down).

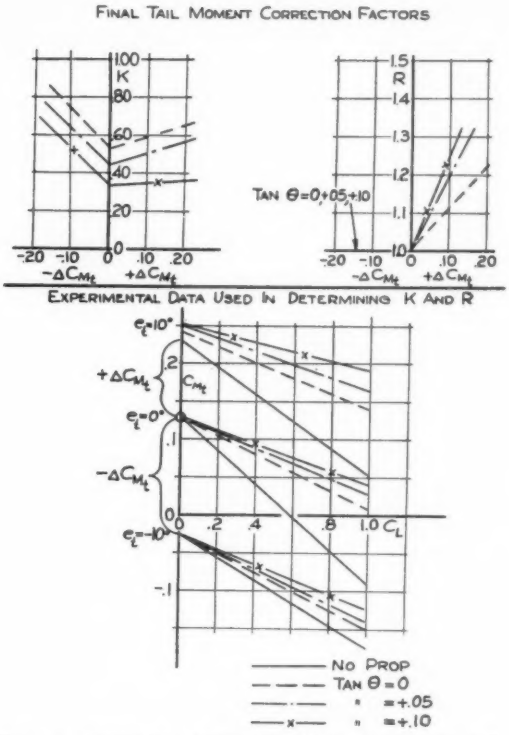


FIG. 5. Correction factors for effect of power-on tail moment coefficient, elevator free; experimental data from which the factors are determined.

This $C_{M_t}$, combined with the moment coefficient due to wing and fuselage alone, will produce an overall $C_M$ *vs.* $C_L$ curve of a similar wavy nature.

Bolster has determined the static longitudinal stability of this model for various powers for wing and fuselage alone.[3] In order to find the effects of slipstream and tab on tail moments, his values of the moment coefficient for wing and fuselage alone (for various powers) were subtracted from the values for the complete airplane model (for corresponding powers).

Values thus obtained were plotted and straight lines were faired through the points below a lift coefficient of 1.0. These faired curves of $C_{M_t}$ *vs.* $C_L$ are shown in the lower portion of Fig. 5.

From a study of these curves it is seen that the effect of power on static longitudinal stability (elevator free) consists of two parts: (1) a change in the slope of the tail moment coefficient curve, $dC_{M_t}/dC_L$, and (2) a change in the intercept for any given change of tab angle from the neutral position.

In the following, primed quantities refer to "power on," unprimed quantities to "no propeller." For "no propeller" (see references 1 and 3).

$$C_{M_t} = -\eta_t \frac{l}{t}\frac{S_t}{S}\left[\left(1 - \frac{a_0}{\pi A.R.}\right)C_L \Big/ \left(1 + \frac{a_0}{\pi A.R._t}\right) - a_0\alpha_d \Big/ \left(1 + \frac{a_0}{\pi A.R._t}\right)\right]$$

$$\therefore \frac{dC_{M_t}}{dC_L} = -\eta_t \frac{l}{t}\frac{S_t}{S}\left[\left(1 - \frac{a_0}{\pi A.R.}\right) \Big/ \left(1 + \frac{a_0}{\pi A.R._t}\right)\right]$$

Let $dC'_{M_t}/dC_L$ = slope, power on, for tab angle in question.

$dC_{M_t}/dC_L$ = slope, no propeller, for tab angle in question.

Adopting notation following that used in reference 3,

$$\mathrm{K} = \left(\frac{dC'_{M_t}}{dC_L}\right) \Big/ \left(\frac{dC_{M_t}}{dC_L}\right)$$

and

$$\Delta\mathrm{R} = \frac{\Delta C'_{M_t}}{\Delta C_{M_t}} = \frac{\text{Change in tail moment coeff. at } C_L = 0 \text{ due to tab angle, power on}}{\text{Change in tail moment coeff. at } C_L = 0 \text{ due to same tab angle, no propeller}}$$

Then $$C'_{M_t} = -\eta_t \frac{l}{t}\frac{S_t}{S}\left[K\left(1 - \frac{a_0}{\pi A.R.}\right)C_L \Big/ \left(1 + \frac{a_0}{\pi A.R._t}\right) - Ra_0\alpha_d \Big/ \left(1 + \frac{a_0}{\pi A.R._t}\right)\right]$$

In explanation, $\Delta C_{M_t}$ = difference between the tail moment coefficient for a given tab setting with "no propeller" and the tail moment coefficient for tab angle zero, "no propeller," both taken at $C_L = 0$.

$\Delta C'_{M_t}$ = the difference between the tail moment coefficient for a given tab setting, "power on" (various values), and the tail moment coefficient for tab angle zero, "no propeller." both taken at $C_L = 0$.

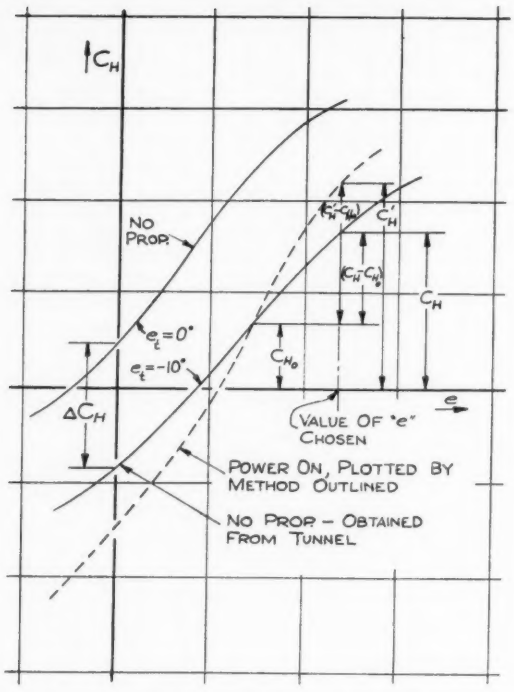


FIG. 6. Diagram defining terms used in hinge moment discussion.

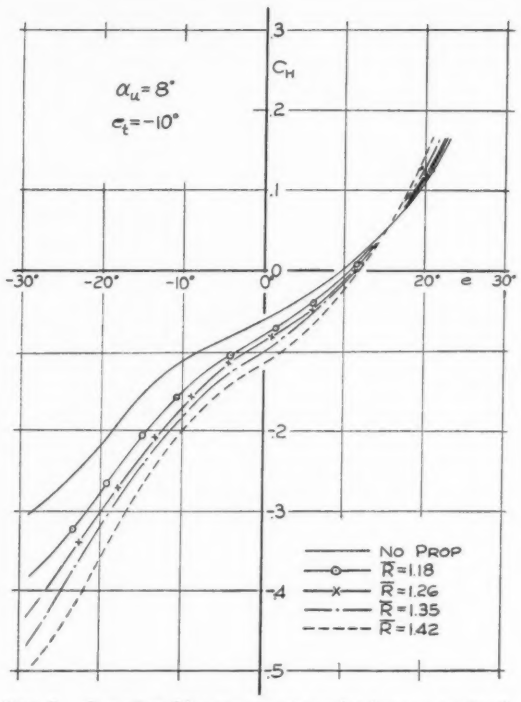


FIG. 7. Complete hinge moment results for one angle of attack and tab angle.

In Fig. 5, values of $K$ and $R$ for various amounts of power and for different tab angles are plotted *vs.* $\Delta C_{M_t}$. It is apparent that a particular value of $\Delta C_{M_t}$ corresponds to a particular tab angle, but the former was used as a parameter in preference to the latter, since it is felt that it has a more basic significance.

It is probable that $K$ and $R$ will vary somewhat with the location of the horizontal stabilizer. This variation was not investigated in this report but was covered in reference 3.

In order to make use of these data and obtain the elevator free pitching moment coefficient of the complete airplane model for "power on," the following procedure is suggested:

(1) Let $(-)$ correspond to no propeller values. Let $(-)'$ correspond to power-on values.

(2) Obtain $C_M$ *vs.* $C_L$ curves for model from wind-tunnel tests. (It is assumed that model has no power plant nor propeller installed but is tested elevator free with various tab angles.)

(3) Obtain $C_{M(\text{no tail})}$ *vs.* $C_L$ curves from wind-tunnel tests.

(4) Obtain $C_{M_t}$ by taking difference (3) and (2) and plot resulting $C_{M_t}$ *vs.* $C_L$ curves for various tab angles (*i.e.*, $\Delta C_{M_t}$'s).

(5) Obtain $K$ and $R$ from Fig. 5 as described above and compute and plot $C'_{M_t}$.

(6) Refer to reference 3 which gives a method for determining $C_{M(\text{no tail with power on})} = C'_{M(\text{no tail})}$.

(7) Obtain final result $C'_M = C'_{M(\text{no tail})} + C'_{M_t}$.

## THE EFFECT OF POWER ON ELEVATOR HINGE MOMENTS (AT VARIOUS TAB ANGLES)

Reference to the hinge moment coefficient ($C_H$) *vs.* elevator angle $e$ curves, shown in Fig. 8, shows that, in general, the hinge moment coefficient is increased by the presence of the slipstream.

The angles of attack investigated were $\alpha_u = -2^1/_2°$, $0°$, $+8°$, and $+16°$. ($\alpha_u = \alpha$ uncorrected for tunnel wall interference.) The tab angles investigated were $e_t = -10°$, $0°$, $+10°$, $+20°$, and $+30°$. Powers investigated are defined in terms of the $\overline{R}$ parameter of power whose meaning has been explained in an earlier portion of this paper.

Fig. 7 is a typical elevator hinge moment coefficient curve of $C_H$ *vs.* $e$ for various powers at a tab angle of $-10°$ and a geometrical angle of attack ($\alpha_u$) of $+8°$. Fig. 8 gives the experimental results for all angles of attack and tab angles investigated. However, only limiting values of the power are included to avoid making the figures undesirably crowded.

Fig. 6 is inserted to aid in clarifying the following discussion:

$C_{H'} = C_H$ with power (see Fig. 6)

$C_H = C_H$ no propeller

$\Delta C_H = C_H(e_t, e = 0, \overline{R} = 1) - C_H(e_t = 0, e = 0, \overline{R} = 1)$

$C_{H_0} = C_H$ where $C_{H'} = C_H$ for tab angle in question

In order to reduce the results of the tests to a form which would be of immediate use to the designer, the

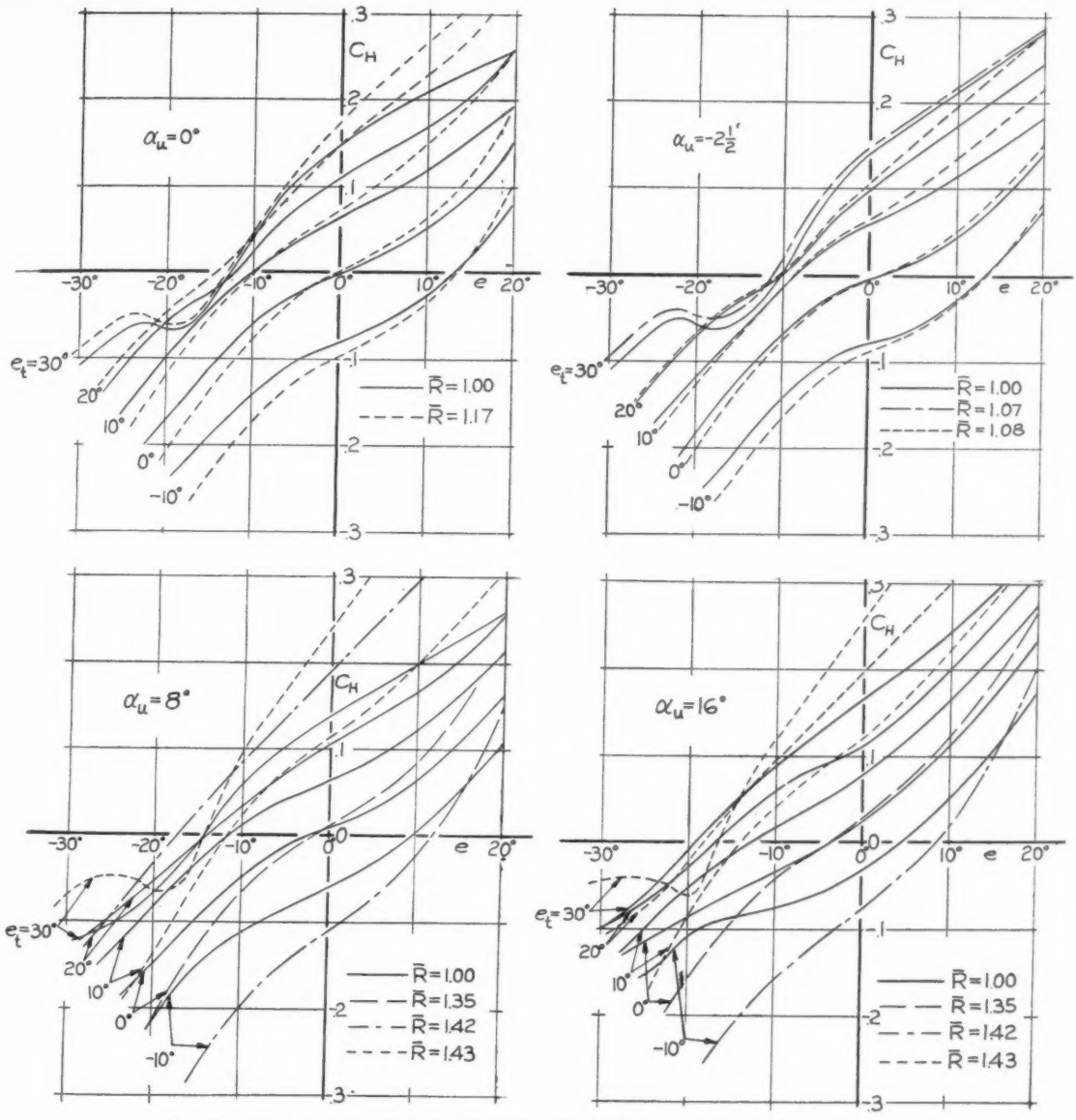


FIG. 8. Hinge moment data for all angles of attack and tab angles investigated.

following procedure was followed in analyzing the experimental data:

(1) $(C_H' - C_{H_0})$ *vs.* $(C_H - C_{H_0})$ is plotted for $\bar{R}$ = constant (see Fig. 9);

(2) The points lie approximately along straight lines given by $(C_H' - C_{H_0}) = (C_H - C_{H_0})\, f(\bar{R})$;

(3) The slopes of these lines, $(C_H' - C_{H_0})/(C_H - C_{H_0}) = f(\bar{R})$, are plotted against $\bar{R}$ (diagram to the left of Fig. 9);

(4) It appears that $f(\bar{R})/\bar{R} = 1.4/1.36$. Therefore $f(\bar{R}) = 1.03\ \bar{R}$, or, within our experimental limits of accuracy, $f(\bar{R}) = \bar{R}$. This result is interesting because it should be thought that the variation would be proportional to the dynamic pressure or $V^2 \sim \bar{R}^2$, instead of $\bar{R}$.

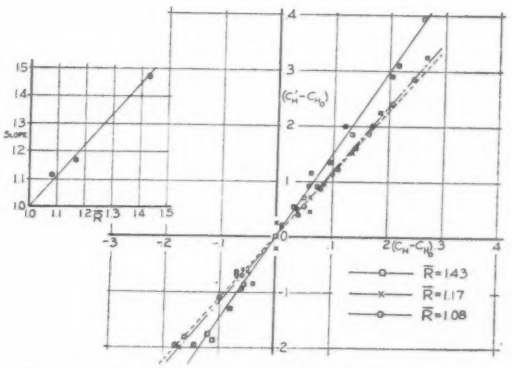


FIG. 9. Replot of experimental hinge moment data.

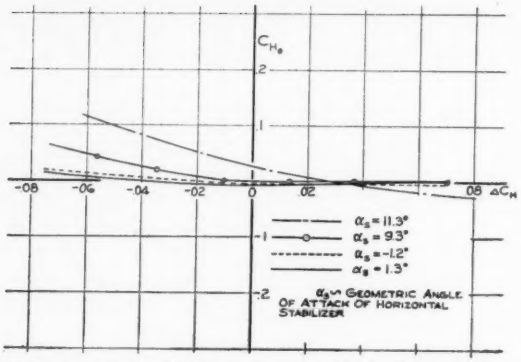


FIG. 10. Value of hinge moment at which slipstream has no effect.

(5) Hence the results are approximately expressed by

$$C_H' - C_{H_0} = \overline{R}\,(C_H - C_{H_0})$$

(6) Values of $C_{H_0}$ are plotted in Fig. 10 as function of $\Delta C_H$ for various values of $\alpha_s$ = geometrical angle of attack of horizontal stabilizer.

In order to make use of these data, $C_H$ *vs.* $e$ curves are obtained from wind-tunnel data at various values of $e_t$ and $\alpha_u$, with power zero. (No power plant is assumed to be installed on the model.) To determine the effect of power on the hinge moment coefficient, proceed as follows:

(1) Determine $\Delta C_H$ as defined above;

(2) Enter Fig. 10 with $\Delta C_H$ and $\alpha_s$ and obtain $C_{H_0}$. Locate this on $C_H$ *vs.* $e$ curve for proper $\alpha_u$ and $e_t$;

(3) Compute $(C'_H - C_{H_0}) = \overline{R}(C_H - C_{H_0})$ for various values of $e$ and plot result as shown in Fig. 6.

The effect of power on static directional stability was investigated for two geometrical angles of attack, that is $\alpha_u = -2°$ and $+8°$. The low angle of attack simulated high-speed conditions and the high angle, low-speed conditions. The rudder angles ranged from 0° to 25°, plus and minus, being varied in increments of 5°. The angles of yaw, $\psi$, investigated ranged through twenty-seven degrees on either side of zero. The power parameter employed in this phase of the investigation was $\overline{R}$, whose significance has been described.

Fig. 11 shows variation of yawing moment coefficient, $C_y$, against $\psi$ for various combinations of rudder angle and power for $\alpha_u = -2°$; $q$ = 30 gm./sq.cm. Similarly, Fig. 12 is plotted for $\alpha_u = +8°$; $q$ = 7 gm./sq.cm. ($q$ = dynamic pressure of the wind-tunnel airstream).

An examination of these curves shows that a change in rudder angle does not appreciably affect stability, $dC_y/d\psi$, but merely varies the $C_y$ intercept at $\psi = 0$ deg. The effect of power also changes the $C_y$ intercept at $\psi = 0$ deg., and, in addition, it appears to cause an increase in directional stability. This increase is only slightly apparent in Fig. 11, but in Fig. 12, the effect is most noticeable.

In order to explain this increase in static directional

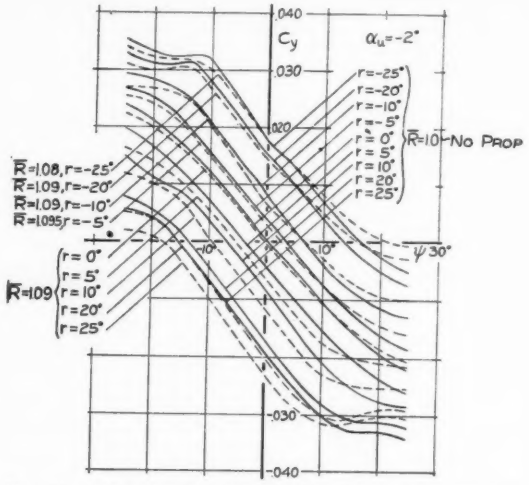


FIG. 11. Directional stability and rudder effectiveness at small angle of attack.

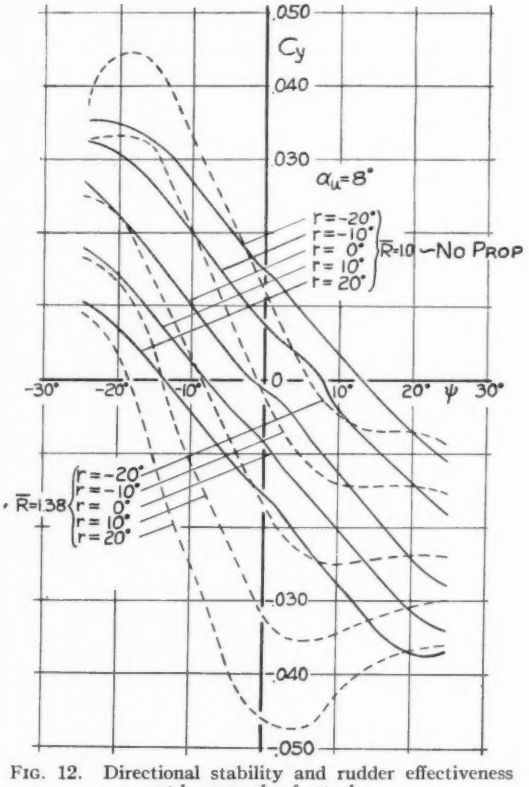


FIG. 12. Directional stability and rudder effectiveness at large angle of attack.

stability with "power on," a qualitative, graphical analysis is used. Referring to Fig. 13, the vertical tail surfaces are shown as viewed from above, for the three conditions of negative, zero, and positive yawing angle. Let vector "*a*" in each case represent the free air flow. Vector "*b*" in each case represents the component of slipstream velocity increment which is parallel to the thrust line. Vector "*c*" in each case represents the athwartship component of slipstream velocity due to

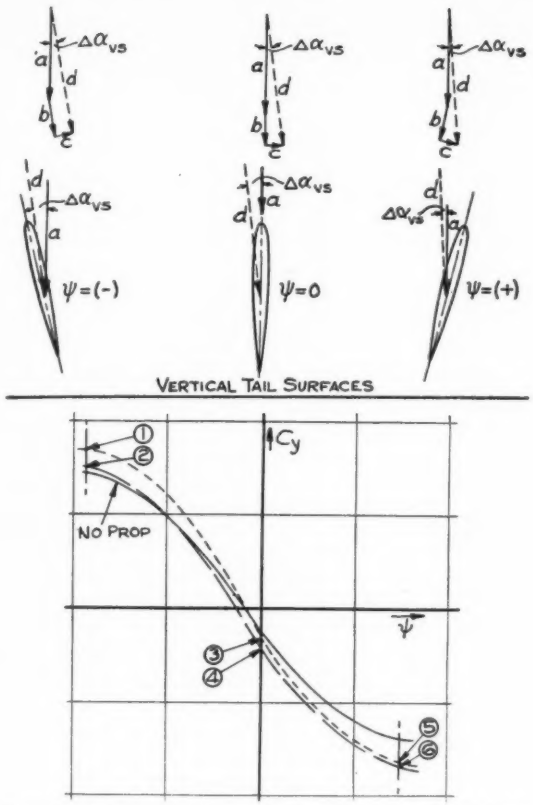


FIG. 13. Diagram showing effect of slipstream on yawing moments.

the upper portion of the slipstream's helix. (The lower portion of the helix is not considered, as no vertical tail surface is present in this region.) The resultant vector "*d*," shown dotted, represents qualitatively the magnitude and direction of the resulting airflow relative to the tail surface. In order to clarify the discussion, vectors "*a*" and "*d*" are also shown immediately adjacent to the tail surfaces. The angle $\alpha_{v.s.}$ is defined as the geometrical angle of attack of the vertical surfaces relative to the wind vectors "*a*" and "*d*," in each of the three cases.

A typical $C_y$ *vs.* $\psi$ curve, "no propeller," is shown by the solid curve in Fig. 13 below the schematic diagram. Consider first only the effect of the increased velocity, due to the presence of the slipstream, on directional stability, disregarding, for the moment, the change in the angle $\alpha_{v.s.}$. Under these idealized conditions, the curve represented by the dotted line is obtained, for the effect of the increased velocity is to multiply the value of the power-off yawing moment by an approximately constant factor.

Now consider the effect of the change in the geometrical angle of attack, $\Delta\alpha_{v.s.}$, of the vertical surfaces. In the case of negative yaw, $\alpha_{v.s.}$ is changed by the amount $\Delta\alpha_{v.s.}$ through the action of the slipstream, as shown in Fig. 13. This produces a negative change in yawing moment and moves point (1) down to some

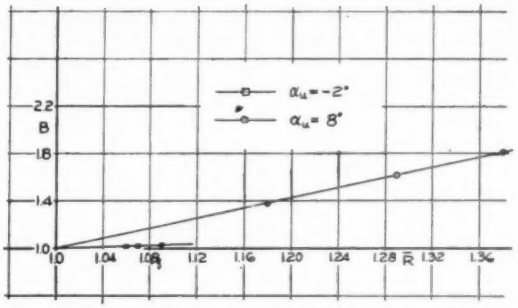


FIG. 14. Ratio of directional stability power-on to that with no propeller.

such position as point (2) in Fig. 13. Similarly, at zero yaw, the angle of attack has been changed by a $\Delta\alpha_{v.s.}$, but, as is clear from Fig. 13, the amount of this change is less than before, so that point (3) is moved down to point (4), a smaller distance than before. At positive yaw, the angle of attack has changed only very slightly as a result of which point (5) is moved only a short distance to point (6). The final "power-on" curve is shown by the long dashed line.

It is seen that the deviation of this "power-on" curve from the "no propeller" curve is quite similar to that of the corresponding experimental curves in Fig. 12. Thus the increase of static directional stability, due to the presence of power, is qualitatively explained.*

In order to get a quantitative measure of the effect of power on static directional stability, define

$$B = \left(\frac{dC_y'}{d\psi}\right) \Big/ \left(\frac{dC_y}{d\psi}\right)$$

where $dC_y'/d\psi$ = slope of $C_y$ *vs.* $\psi$ curve, power on
$dC_y/d\psi$ = slope of $C_y$ *vs.* $\psi$ curve, no propeller

Fig. 14 shows a plot of $B$ *vs.* the power parameter $\bar{R}$ for the two angles of attack investigated.

* In the near future, tests are to be conducted in the GALCIT wind tunnel with the power model less its tail surfaces, to determine the effect of power on static directional stability due to vertical tail surfaces alone. When these results become available, it is hoped that the analysis of this effect of power can be explained on a more exact quantitative basis.

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# An Integrator for Evaluating the Downwash from a Span-Loading Curve

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(Received December 29, 1937)


## Summary

A MECHANICAL integrator is described that evaluates the downwash directly from a span-load distribution of a wing. A mathematical analysis of the functioning of the machine is included.


## Introduction

The purpose of this paper is to describe a mechanical integrator that derives the downwash distribution directly from a span-loading curve for any particular wing. Such a machine finds its application in checking span-load distributions that may have been either obtained by a Fourier series analysis or assumed in the process of an example of the iteration, or successive-approximation, method.

In use, the integrator is set to the spanwise station for which the downwash is desired, a tracing pointer is run over the loading curve from wing-tip point to wing-tip point, and the value of the downwash is then read directly from the instrument. The distribution of downwash thus obtained, together with the geometry and attitude of the wing and the aerodynamic characteristics of its profiles, produces a new or *check* loading curve that should agree with the one from which it was derived, providing that that curve be the true span-load distribution for the wing.

The downwash integrator evaluates the relationship, derived from lifting-line airfoil theory, between the downwash at any span station and the shape of the loading curve itself. Mathematically, this relation may be expressed in a form such as:

$$\left(\frac{w}{v}\right)_{y=y_1} = \frac{1}{8\pi}\int_{y=\frac{b}{2}}^{y=-\frac{b}{2}} \frac{d(c_l c)/dy}{y - y_1}\, dy \qquad (1)$$

where

- $(w/v)_{y=y_1}$ is the downwash angle in radians at the spanwise point $y_1$.
- $c_l$, the section lift coefficient.
- $c$, the section chord.
- $y$, the spanwise distance of the loading curve corresponding to $c_l c$ measured from the wing-span center line.

Theoretically, the machine should experience no difficulty from the region of the singular point $y = y_1$; but, in actual practice, large indeterminate errors would undoubtedly be introduced should the tracing pointer pass through the singularity in the usual manner. This difficulty may be avoided, however, if that small portion of the curve is assumed to be expressible by a power series of a few terms and evaluated by making the tracing pointer in this region follow a rectilinear path paralleling the coordinate axes. The error involved in such an approximation is effectively nil, being a function of the disagreement possible between the series and the element of the curve it replaces.

The remainder of this paper will be concerned with a schematic description of the integrator and its operation. A simple mathematical proof of the machine and the method of handling the singular point $y = y_1$ will be given in the appendix.

## Description

Fig. 1 is a diagrammatic plan drawing of the downwash planimeter linkage. The drawing does not attempt to show a construction of the machine nor the relative sizes or the final arrangement of the component parts; it is intended only to enable one to visualize the principles of the instrument and the manner of its operation by means of an illustrative description.

The kinematics of the downwash planimeter is indicated in Fig. 1. In following the span-loading curve $B$, the tracing pointer $A$ irrotationally translates the carriage $I$. The carriage is free to move along the table $K$ in the $y$ direction, and the table and carriage are free to move together in the $c_l c$ direction. The motion of the tracing pointer is thereby resolved into its $c_l c$ components, corresponding to the displacements of the table relative to the loading curve, and its $y$ components, corresponding to the displacements of the carriage relative to the table. Resting on the table is the "keel" wheel $E$ and its mounting. The keel wheel is so called because, by virtue of its sharp edge and its mounting, it moves together with the table in the $c_l c$ direction but when acted upon by a displacement of the carriage, it always moves in the plane of its edge. The carriage is designed so as to determine only the $y$ coordinate of the keel wheel. The overhead pivot $H$ is adjustably fixed with respect to the loading curve. Its $y$ coordinate is made to correspond with the $y_1$ station for which the downwash is desired. Swung from this pivot is the overhead beam $G$, along which the keel wheel is free to

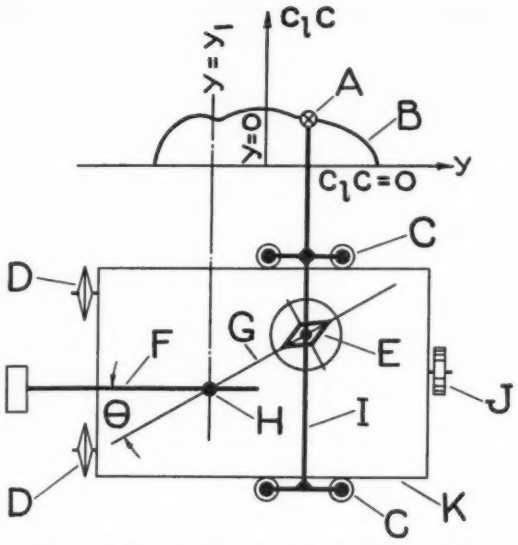



FIG. 1. Schematic diagram of the downwash planimeter.

*A.* Tracing pointer on carriage *I*.

*B.* Span-load distribution, curve of $c_l c$ against $y$.

*C.* Wheel trucks supporting carriage *I* running on moving table *K*.

*D.* Sharp-edged wheels, which may roll in a grooved track, supporting moving table *K* and allowing it to move parallel to the $c_l c$ axis.

*E.* Sharp-edged "keel" wheel, rolling on the moving table *K* whose $y$ position is determined by the carriage *I*.

*F.* Overhead arm that is motionless with respect to the span-load distribution *B* and which supports the pivot *H*.

*G.* Overhead beam that directs the plane of the edge of the keel wheel *E* and along which the keel wheel is free to move under the influence of the carriage *I*.

*H.* Overhead pivot that is fixed with respect to the span-load distribution *B* and whose $y$ position can be adjusted to the $y_1$ value for which the downwash is desired. The overhead beam *G* is hung from this pivot and alines the plane of the edge of the keel wheel *E* to include the axis of the pivot.

*I.* Carriage bridging moving table *K* and free to move parallel to $y$ axis.

*J.* Flat-edged wheel supporting moving table *K*.

*K.* Moving table whose plane is parallel to that of the span-load distribution *B* and which is free to move parallel to the $c_l c$ axis.

$\theta$. Angle between plane of edge of keel wheel *E* and $y$ axis; $\theta$ is the reading of the instrument.

move on the table. The overhead beam alines the plane of the edge of the keel wheel through the axis of the pivot. Motion of the table, therefore, varies the angle, $\theta$, between the plane of the keel wheel and the $y$ axis; motion of the carriage varies the $y$ position of the point of contact between the keel wheel and the table. Increments to the tangent of $\theta$ are then inversely proportional to the values of $y - y_1$ and directly proportional to the increments in the value of $c_l c$ that are associated with the movement of the tracing pointer. The full relationship will be given in the proof in the appendix. It might be noted in passing that $\theta$ should not be allowed to approach too closely the value of $\pi/2$ in order to avoid possible errors that might be caused by any resulting slippage of the keel wheel. This precaution can be observed both in the design of the proportions of the instrument and in the operation itself.

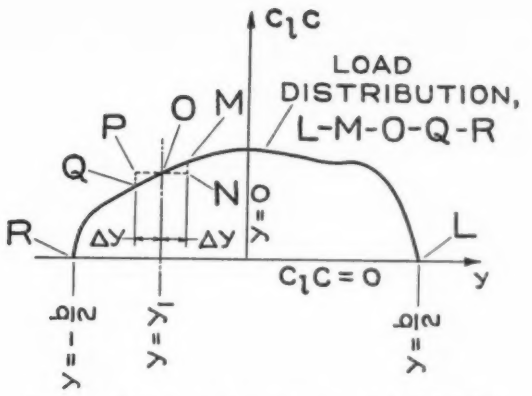



FIG. 2. Path of tracing pointer: *L-M-N-O-P-Q-R*.

Reading of downwash integrator:

$$\left(\frac{w}{v}\right)_{y = y_1} = \frac{1}{8\pi}\left[(\tan\theta_M - \tan\theta_L) + 2(\tan\theta_Q - \tan\theta_M) + (\tan\theta_R - \tan\theta_Q)\right]$$

## OPERATION

The instrument is operated as follows: The downwash planimeter is first adjusted in position with respect to the curve of span-load distribution as indicated in Fig. 1. The motion of the table must be parallel to the $c_l c$ axis, and the $y$ coordinate of the pivot must correspond to the $y_1$ station for which the downwash is to be obtained. The motion of the pointer over the loading curve, in the manner to be described, should fall within the physical range of the linkage, and $\theta$ should not approach too closely the value of $\pi/2$. It will be necessary to find the maximum permissible value of $\theta$ from experiment; this value could be satisfied by the manner of following the curve. Fig. 2 shows the path to be taken by the tracing pointer.

If the span-load distribution is not drawn too large with respect to the linkage of the machine, too large values of $\theta$ will not ordinarily be encountered except in the small region about the singular point $y = y_1$. In this region, as indicated in Fig. 2, the tracing pointer should be made to follow a rectilinear path paralleling the coordinate axes. The small distance, $\Delta y$, should be only large enough to limit the magnitude of $\theta$ to well below the experimentally determined maximum permissible before the keel wheel fails to track, which is some value near $\pi/2$.

The reading of the instrument is defined in Fig. 2 and gives the downwash for $y_1$ directly because the scale is suitably calibrated as explained in the appendix.

## APPENDIX

(1) The relationship between the downwash at any span position and the shape of the loading curve is:

$$\left(\frac{w}{v}\right)_{y=y_1} = \frac{1}{8\pi}\int_{y=\frac{b}{2}}^{y=-\frac{b}{2}} \frac{d(c_l c)/dy}{y - y_1}\, dy \qquad (1)$$

This equation can be simply written

$$\left(\frac{w}{v}\right)_{y=y_1} = \frac{1}{8\pi}\int_{y=\frac{b}{2}}^{y=-\frac{b}{2}} \frac{d(c_l c)}{y - y_1} \qquad (2)$$

From Fig. 1, if $S$ is the distance between the pivot $H$ and the point of contact between the keel wheel $E$ and the table $K$,

$$y - y_1 = S\cos\theta \qquad (3)$$

An infinitesimal displacement of the tracing pointer $A$ in the $c_l c$ direction produces an equal displacement of the keel wheel $E$ relative to the pivot $H$. At the limit,

$$d\theta = d(c_l c)\cos\theta/S \qquad (4)$$

Substituting from Eq. (3)

$$d\theta/\cos^2\theta = d(c_l c)/(y - y_1) \qquad (5)$$

from which

$$\frac{1}{8\pi}\int_{\theta_{b/2}}^{\theta_{-b/2}} \sec^2\theta\, d\theta = \frac{1}{8\pi}\int_{y=\frac{b}{2}}^{y=-\frac{b}{2}} \frac{d(c_l c)}{y - y_1} = \left(\frac{w}{v}\right)_{y=y_1} \qquad (6)$$

Therefore

$$\left(\frac{w}{v}\right)_{y=y_1} = \frac{1}{8\pi}\int_{\theta_{b/2}}^{\theta_{-b/2}} \sec^2\theta\, d\theta = \frac{1}{8\pi}\left[\tan\theta\right]_{\theta_{b/2}}^{\theta_{-b/2}}$$

or

$$\left(\frac{w}{v}\right)_{y=y_1} = \frac{1}{8\pi}\left[\tan\theta_{-\frac{b}{2}} - \tan\theta_{\frac{b}{2}}\right] \qquad (7)$$

The scale of the instrument can be calibrated to read $(1/8\pi)\tan\theta$ and the final reading minus the initial reading is the downwash angle in radians for the spanwise station $y_1$.

2. For the region of the singular point $y = y_1$ in Fig. 2, let $y - y_1 = z$ and assume that between the limits $\Delta y$ and $-\Delta y$

$$c_l c = e + fz + gz^2 \qquad (8)$$

Then

$$d(c_l c) = fdz + 2gzdz$$

and

$$\frac{1}{8\pi}\int_{\Delta y}^{-\Delta y} \frac{d(c_l c)}{z} = \frac{1}{8\pi}\left[f\int_{\Delta y}^{-\Delta y}\frac{dz}{z} + 2g\int_{\Delta y}^{-\Delta y} dz\right]$$

or

$$\frac{1}{8\pi}\int_{\Delta y}^{-\Delta y} \frac{d(c_l c)}{z} = \frac{1}{8\pi}\left[f\log z + 2gz\right]_{\Delta y}^{-\Delta y} \qquad (9)$$

Log $z$ between the limits is imaginary and

$$\frac{1}{8\pi}\int_{\Delta y}^{-\Delta y} \frac{d(c_l c)}{z} = -\frac{1}{8\pi}(4g\,\Delta y) \qquad (10)$$

Evaluating the constant $g$ by substituting values of $c_l c$ at $z = -\Delta y$, 0, and $\Delta y$ in Eq. (8) gives the result

$$-\frac{1}{8\pi}(4g\,\Delta y) = \frac{1}{8\pi}\left\{2\left[\frac{(c_l c)_0 - (c_l c)_{\Delta y}}{\Delta y} - \frac{(c_l c)_{-\Delta y} - (c_l c)_0}{\Delta y}\right]\right\} \qquad (11)$$

The expression $-(1/8\pi)(4g\,\Delta y)$ is the contribution of the loading curve between the limits $y_1 - \Delta y$ and $y_1 + \Delta y$ to the downwash at $y_1$. From Fig. 2, Eq. (11) is seen to be equivalent to

$$(1/8\pi)[2(\tan\theta_Q - \tan\theta_M)] \qquad (12)$$

which is twice the actual reading of the instrument for the path *M-N-O-P-Q*.

Eq. (8) employs sufficient terms for any ordinary application. If the accuracy is ever believed insufficient, an evaluation similar to Eq. (12) but employing more terms of the power series in Eq. (8) can be derived.

# Sixth Annual Meeting of The Institute of the Aeronautical Sciences

THE Sixth Annual Meeting of the Institute of the Aeronautical Sciences, Inc., was held in the Pupin Physics Laboratories of Columbia University at 5:00 p.m., on Wednesday, January 26, 1938. Dr. Clark B. Millikan, President of the Institute, presided. Lester D. Gardner acted as Secretary.

The reading of the minutes of the previous annual meeting was omitted with the approval of the meeting as they had been published in the Journal.

The Annual Reports of the President, the Treasurer, and the Secretary were read and duly approved.

## The President's Annual Report

During the fifth year of its existence, the Institute has further strengthened its position as the outstanding Society of this country whose province covers the fields of scientific and technical aeronautics. It has not only deepened and intensified its activities along lines which had already been established, but has also widened the scope of its contributions in several important directions.

*Formation of Branches.* One of the most important of these new developments has almost certainly been the formation of branches in various parts of the country. In view of the great distances separating many of the aeronautical centers of the country, the Institute has always had the policy of fostering local meetings in addition to those few national gatherings which it sponsors each year. The plan of organization of the Institute's branches, which was adopted this year, provides a carefully planned type of organization which has already shown promise of greatly stimulating the frequent local contacts and interchanges of ideas which form the backbone of any scientific or technical society. Branches of the Institute were formally organized on October 15, the fifth anniversary of the incorporation of the Institute, in New York, Los Angeles, Philadelphia, and Washington, and other branches have since been formed or are in the process of organization.

*Wright Brothers Lecture and Honors Night.* On December 17 last, the Institute inaugurated a series of lectures which seem destined to occupy an important place in American aeronautical life: the Wright Brothers' Lecture, commemorating the first flights of the Wright Brothers, which is to be delivered on alternate years by American and foreign aeronautical leaders. The Lecture this year was given by Professor B. Melvill Jones of Cambridge, England, and was an outstanding success in presentation, discussion, and attendance. The Lecture was followed by the first formal Honors Night Meeting of the Institute, at which the Institute's Reed and Sperry Awards were presented, as well as the Daniel Guggenheim Medal and the Honorary Memberships and Fellowships of the Institute. This Meeting was attended by a remarkably representative group of leaders in American aeronautics, and promises to take its place as one of the major events in the aeronautical calendar. Through the courtesy and cooperation of several of the airlines, it was possible for the Wright Brothers' Lecture to be repeated a few days after its initial presentation at the California Institute of Technology on the Pacific Coast, where again it was received most enthusiastically by a large audience of scientists and engineers.

*The Vernon Lynch Endowment.* One of Mr. Sherman M. Fairchild's guests at the Honors Night Meeting, Mr. Edmund C. Lynch of New York, was so impressed with the appropriateness of the commemorative ceremony that he sent a letter with securities valued at $10,335, yielding an income of over $800 a year. His letter states: "*So strongly am I of the opinion that the Wright Brothers' Lecture will bring disclosures of advances which will be of practical benefit to aviation—that the Honors Night plan of commemorating this anniversary is so worthy of the occasion—that I believe the Institute should continue this work. With this in view I desire to make a contribution to the Institute, the principal of which is to be held intact and the income therefrom applied annually toward the accomplishment of this purpose. This contribution is in commemoration of my brother, Mr. Vernon Lynch.*"

I wish to express to Mr. Lynch the great appreciation of the Officers and Members of the Institute for his generosity which assures a continuation of this anniversary ceremony, of which Col. Charles A. Lindbergh wrote: "*I cannot recall attending a similar occasion which I feel was as well planned and carried out. You combined interest and enthusiasm with dignity and appropriateness in a manner which is unprecedented in my experience.*"

*Membership.* During the year the list of Benefactor Memberships was increased by two. Mr. Lynch's gift has already been mentioned. The Institute deeply appreciates the gift of Mr. R. H. Fleet of $1000. The number of Corporate Memberships has also been increased. Because of these contributions and dues, the Institute has been able to stay within its budget, in spite of enlargement in the scope of its activities. The list of Corporate Members is now fairly representative of the industry, but a considerable number of large and successful companies is still not included. If these organizations would become Corporate Members, the Institute could do work which is necessary without having to face the ever present danger of a deficit. During the last three months, the Institute has had a loss of over One Thousand Dollars. Members know from reading the Appreciation Page in the Journal each month the names of the companies that make the publication of the Journal possible. During the past five years, we have received splendid support from many firms. It only requires that several other outstanding companies assist the Journal as they do other publications through advertising for the Journal to be of still greater value.

*Meetings.* The increased scope of the Institute's activities is nowhere more apparent than in connection with the meetings which it has sponsored during the past year. In addition to a large number of local meetings, held under the auspices of the various sections, the Institute as a whole has held a number of important meetings. The Annual Technical Meeting, the Honors Night Meeting, and the two meetings connected with the Wright Brothers' Lecture have already been mentioned. In addition to these, important technical sessions have been held at Dayton, at Denver in connection with the American Association for the Advancement of Science, at Cleveland at the time of the National Air Races, and recently at Indianapolis, again in connection with the A.A.A.S. The influence and prestige of the Institute throughout the country have been greatly augmented by these technical sessions held in such widely separated regions.

*Student Activities.* One of the healthiest signs of the recent development of the Institute has been the increased activity of the Student Branches. The number of Student Memberships and of Student Branches has grown greatly during the past year, and practically all of these Branches have been extremely active. Since the membership and strength of the Institute during the next decade will be drawn largely from the present student groups, this development augurs well for the Institute's future.

*Journal.* Under the expert and painstaking guidance of Dr. J. C. Hunsaker, the Journal can again report the continued improvement in scope and quality which we have annually come to expect, without realizing the time and effort which are responsible for it. One of the most important problems the Institute has to face is that of supplying adequate editorial assistance so that some of this great burden may be removed from Dr. Hunsaker. The securing of additional Corporate Members is the essential first step toward the solution of this problem.

*Index.* It is once again a pleasure to express the Institute's appreciation to the Works Progress Administration for its continued support of the Aeronautical Index. During the past year, sixteen bibliographies have been prepared and distributed, covering a wide range of aeronautical fields. These bibliographies, which have been compiled from the Index, represent invaluable contributions to the aeronautical literature. Additional volumes are in preparation and will appear during this year.

*Non-Technical Activities.* During the past year, the Institute has cooperated with the Lilienthal-Gesellschaft and the Royal Aeronautical Society in assisting with arrangements for guest speakers. The Institute has also acted as host or sponsor at a large number of dinners and other meetings in honor of distinguished foreigners and Americans, and has served as a focus for many pleasurable and valuable aeronautical gatherings. The new and more adequate offices, for which we are largely indebted to Rockefeller Center, have already proven to be essential to the adequate carrying on of these activities.

It is your President's pleasant privilege to express the Institute's formal appreciation for the tireless efforts of your Secretary, whose judgment and activity have been so largely responsible for the continued progress of the Institute during this last year. The Institute's indebtedness to Major Gardner, and to the able group of assistants he has collected around him, cannot possibly be measured.

In closing, may I express my personal thanks to the officers and members of the Council and to your Secretary for their support during the past year, and thank them on your behalf for their guidance and leadership in carrying the Institute forward through another year of steady growth and progress.

CLARK B. MILLIKAN

## ANNUAL BALANCE SHEET
## AS OF SEPTEMBER 30, 1937

**ASSETS**

| | | |
|---|---|---|
| Cash on Hand and in Bank | | $291.60 |
| Accounts Receivable | | 643.14 |
| *Investments of Unrestricted Funds* | | |
| The Benefactor Membership Fund: | | |
| U. S. Treasury Bonds at Par Value (Market $6,024.37) | $6,000.00 | |
| Bond Premium (Balance) | 56.57 | |
| Total Benefactor Membership Fund | | 6,056.57 |
| *Investments of Restricted Funds* | | |
| The S. A. Reed Fund: | | |
| U. S. Treasury Bond at Par Value (Market $10,040.62) | 10,000.00 | |
| Accrued Interest Receivable on Bond | 11.98 | |
| Cash on Deposit for Award | 261.20 | |
| Total S. A. Reed Fund | | 10,273.18 |
| The Lawrence Sperry Fund: | | |
| U. S. Treasury Bonds at Par Value (Market $2,008.12) | 2,000.00 | |
| Accrued Interest Receivable on Bonds | 1.20 | |
| Cash on Deposit for Award | 303.58 | |
| Total Lawrence Sperry Fund | | 2,304.78 |
| Office Furniture and Equipment | 5,718.51 | |
| Less—Reserve for Depreciation | 2,772.68 | |
| Net Total | | 2,945.83 |
| Prepaid Expenses | | 982.56 |
| **Total Assets** | | 23,497.66 |

**LIABILITIES**

| | | |
|---|---|---|
| Accounts Payable | | None |
| *Reserves* | | |
| 1938 Dues Paid in Advance | 512.50 | |
| Unearned Corporate Member Dues | 3,687.01 | |
| Unearned Subscriptions | 1,417.50 | |
| Total Reserves | | 5,617.01 |
| *Restricted Funds* | | |
| The S. A. Reed Fund | $10,000.00 | |
| Net Income of Fund | 273.18 | 10,273.18 |
| The Lawrence Sperry Fund | 2,000.00 | |
| Net Income and Donation | 304.78 | 2,304.78 |
| Total Restricted Funds | | 12,577.96 |
| *Unexpended Income* | | |
| Balance, October 1, 1936 | 4,894.55 | |
| Net Unexpended Income for Year Ended September 30, 1937 | 408.14 | |
| Balance, September 30, 1937 | | 5,302.69 |
| **Total Liabilities and Unexpended Income** | | 23,497.66 |

## THE TREASURER'S ANNUAL REPORT

Your Treasurer submits to the membership, as required by the By-Laws, the Annual Statement of the Institute for the fiscal year ended September 30, 1937. Patterson & Ridgeway, certified public accountants, in submitting the report wrote:

*"We have made a limited examination of the books of account of the Institute of the Aeronautical Sciences, Inc., for the fiscal year ended September 30, 1937, and submit our report thereon.*

*"We traced the recorded receipts to the statement of your depository, examined the invoices and cancelled checks supporting the cash disbursements, reconciled and confirmed the bank balance. Cash book footings were checked and journal entries were examined.*

*"We made a physical inspection of the bond investments. We tested the other accounting records of the Institute, obtaining information and explanations from officers and employees but did not make a detailed audit of the transactions.*

*"In our opinion, based on such examination, the accompanying statements fairly present the financial position of the Institute at September 30, 1937, and the results of operations for the fiscal year then ended."*

*Assets.* From the Balance Sheet it will be seen that the assets of the Institute have increased. This was principally due to the gifts of $1000 from R. H. Fleet and an additional $1000 received for the Lawrence Sperry Award Fund. If this statement were as of December 31 instead of September 30, it would show a further increase of over $10,000 due to the generous gift of Mr. Edmund C. Lynch in establishing the Vernon Lynch Fund.

It will be noted that the Benefactor Membership Fund of $6000 is approximately the same as the unearned dues and subscriptions which cannot be charged as income until the period for which they are paid has expired.

*Income and Expenditures.* The statement of Income and Expenditures reflects the precarious financial condition of the Institute. It shows that during the year the income of the Institute increased by slightly more than the $1000 which was given by Mr. Fleet. Actually there was a decrease in general receipts which was made up by an increase in revenue from the publication of the Journal.

To operate on this small operating budget was possible by the employment of only a minimum staff. An editor for the Journal could not be employed and Dr. Hunsaker continued his invaluable voluntary work. It was not even possible to engage a stenographer, a condition which makes the work of the Secretary doubly difficult.

The brightest spot in the statement was the increase of dues from Corporate Members of about $3000. It will be seen that all the dues of Corporate Members are charged to the publication of the Journal. Of course, this is a matter of bookkeeping procedure and the net income from the Journal, while substantial, could not

## Statement of Income and Expenses for the Fiscal Year Ended September 30, 1937

| | | | |
|---|---|---|---|
| **INCOME** | | | |
| Dues (Net after applying $5.00 per member for Journal) | | $3,023.58 | |
| Initiation Fees | | 450.00 | |
| Benefactor Membership | | 1,000.00 | $ 4,473.58 |
| Net Income from Journal Publication (see details below) | | | 7,556.66 |
| **Total Income** | | | 12,030.24 |
| **EXPENSES** | | | |
| Administration, Clerical and Accounting | | 6,931.00 | |
| Rent | | 725.00 | |
| Certificates of Membership | | 492.37 | |
| Electricity, Telephone and Telegraph | | 284.14 | |
| Office Supplies, Printing, and Stationery | | 387.81 | |
| Postage | | 428.85 | |
| Travel and Entertainment | | 675.32 | |
| Library and Index | | 264.49 | |
| Meetings: | | | |
| Expense | $3,822.12 | | |
| Less—Income | 3,307.92 | 514.20 | |
| Uncollectible Accounts | | 106.78 | |
| Depreciation | | 675.99 | |
| Miscellaneous | | 136.15 | |
| **Total Expenses** | | | 11,622.10 |
| **Net Unexpended Income for the Fiscal Year** | | | 408.14 |

## Detail of Journal Income and Expenses

| | | | |
|---|---|---|---|
| **INCOME** | | | |
| Corporate Member Dues | | $13,775.21 | |
| Subscriptions Earned* | | 10,681.70 | |
| Reprints | | 130.90 | |
| **Total Journal Income** | | | 24,587.81 |
| **EXPENSES** | | | |
| Administration, Clerical, and Accounting | | $6,931.00 | |
| Engraving | | 1,157.21 | |
| Postage | | 743.17 | |
| Printing | | 6,318.78 | |
| Office Supplies and Stationery | | 113.16 | |
| Rent | | 725.00 | |
| Electricity, Telephone and Telegraph | | 284.13 | |
| Travel and Entertainment | | 683.82 | |
| Miscellaneous | | 74.88 | |
| **Total Expenses** | | | 17,031.15 |
| **Net Income from Journal Publication (to Institute Income)** | | | 7,556.66 |

* Includes Corporate Member Journal Subscriptions at $5.00 each, and all receipts from Student Member dues.

have been made without other Institute expenditures which it is used to defray.

The main problem before the Institute is how to interest other companies engaged in the aviation industry, to assist the Institute in the publication of the Journal so that the Treasurer will not have constant worry about meeting the expenses.

I feel that members should note particularly that the income from dues from members, after applying $5 for their subscriptions to the Journal, was only about $3000. In other words, the dues from Corporate Members made the publication of the Journal and operation of the Institute possible.

The Institute faces a critical financial condition. If it had not been for Mr. Fleet's gift and if the cost of the Membership Roster, which appeared in September, had been charged to 1937, the Institute would have lost about $1300 for the year instead of showing a gain of $400. This condition is reflected in the more recent statement of December 31, 1937, which shows a deficit of $1021.61. This will have to be offset by curtailment of activities by the Institute during the year if some of the companies mentioned above do not contribute to the Journal.

The Institute is a natural recipient for aeronautical endowments. This is seen by the funds already received during the past five years. It is also shown by the fact that one friend has made a bequest in his will of securities valued at over a half a million dollars. Other gifts and bequests would come if the aircraft industry would only contribute to the Journal as they do to other publications and other aeronautical organizations.

Your Treasurer is not pessimistic regarding the future of the Institute. He knows that the fine work already done will be followed by an expansion rather than a curtailment of activities. But he would not feel he had done his duty to members unless he gave them the exact situation as reflected from the financial statement.

Elmer A. Sperry, Jr.

## The Secretary's Annual Report

*Membership.* The Membership Report as of January 1, 1938 is as follows:

*Division of Membership—January 1, 1938*

| | *Foreign* | *American* | *Total* |
|---|---|---|---|
| Honorary Fellows | 6 | 7 | 13 |
| Honorary Members | 0 | 7 | 7 |
| Fellows | 0 | 74 | 74 |
| Temp. Honorary Members | 0 | 4 | 4 |
| Associate Follows | 186 | 402 | 588 |
| Industrial Members | 12 | 136 | 148 |
| Pilot Members | 7 | 67 | 74 |
| Technical Members | 14 | 382 | 396 |
| Student Members | 0 | 662 | 662 |
| Total | 225 | 1736 | 1961 |

| | |
|---|---|
| Total Membership on January 1, 1937 | 1535 |
| Members elected during 1937 | 470 |
| Members resigned during 1937 | 12 |
| Members deceased during 1937 | 7 |
| Members dropped during 1937 | 25 |
| Total Membership on January 1, 1938 | 1961 |

As will be seen from the above, the Institute made a substantial gain in membership during 1937. The net gain of 426 came mainly from an increase of 229 Student Members and 169 Technical Members. The Admissions Committee have used great care in approving the grading of members and should receive the appreciation of all members for their painstaking work.

*The Journal.* At the suggestion of several officials of aircraft companies which wished to aid financially in the publication of a scientific and technical journal by the Institute, the acceptance of advertising was discontinued and the Corporate Membership idea was substituted. It was believed that such a plan would save the aircraft companies the cost of the payment of agent's commission and for the preparation of copy, plates, etc. and it would save the Journal the cost of handling and printing the advertising. In its place Corporate Members were to be given a listing on an Appreciation Page, some subscriptions to the Journal and a page advertisement in the Annual Roster. After one year's trial the plan is obviously not a success. Companies which had contracted for over one thousand dollars of advertising became Corporate Members at the minimum rate of $200 a year. Only five of the large aircraft and engine manufacturing companies became Corporate Members although practically all the others advertise in other aeronautical publications, paying many times the amount of Corporate Membership dues. Every possible argument has been presented to these non-cooperating companies without success. The Journal has only one Corporate Member located west of Chicago.

Your Secretary has always been opposed to the acceptance of advertising by publications issued by societies and associations in competition with the trade publications in the same field. He has stood almost alone in holding this point of view and he was glad to have the Journal try the experiment. Unfortunately he has become disillusioned by the results. He finds that unless some companies can have their advertising copy appear in a publication they regard Corporate Dues as a contribution without adequate return. With only five Corporate Members from a score of aircraft and engine companies, the members of the Institute should consider seriously whether the aircraft industry as a whole wishes to continue encouraging the publication of a scientific or technical publication.

*Institute Headquarters.* Through the considerate action of Rockefeller Center the Institute has been able to move to adequate offices where all the publishing, Index, and Library activities could be in one place.

*Library.* While the library is being gradually enlarged principally through receiving books sent for review, the Secretary again urges members to send aeronautical books as gifts to the library.

*Gifts and Bequests.* The President's Report has expressed the gratitude of the Institute to donors for their gifts as Benefactor Members. Other members and friends, who may be considering making gifts or bequests to the Institute, may wish to know the status of the Institute regarding exemption from taxation. The following ruling hs been secured from the Commissioner of Internal Revenue: "*Contributions to your organization by individual donors are deductible by such individuals in computing their taxable net income, in the manner and to the extent provided by section 23 (o) of the Revenue Act of 1936 and the corresponding provisions by prior revenue acts. The deductibility of contributions by corporations is governed by section 23 (q) of the Revenue Act of 1936.*

Section (o) states: "*In the case of an individual, contributions or gifts made within the taxable year to or for the use of: . . a corporation . . . organized and operated exclusively for . . . scientific . . . purposes, . . . no part of the net earnings of which inures to the benefit of any private shareholder or individual, and no substantial part of the activities of which is carrying on propaganda, or otherwise attempting to influence legislation; . . . to an amount which in all the above cases combined does not exceed 15 per centum of the taxpayer's net income as computed without the benefit of this subsection. . . .*"

Section (q): "*Charitable and Other Contributions by Corporations. . . . In the case of a corporation, contributions or gifts made within the taxable year to or for the use of a domestic corporation, . . . . organized and operated exclusively for . . . . scientific . . . . purposes . . . . no part of the net earnings of which inures to the benefit of any private shareholder or individual, and no substantial part of the activities of which is carrying on propaganda, or otherwise attempting, to influence legislation; to an amount which does not exceed 5 per centum of the taxpayer's net income as computed without the benefit of this subsection. Such contributions or gifts shall be allowable as deductions only if verified under rules and regulations prescribed by the Commissioner, with the approval of the Secretary.*"

As these rules have been complied with, gifts or bequests to the Institute may be made by generous friends and Corporate Members with the assurance of their being able to deduct such donations from their income taxes.

*Special Funds.* While the annual upkeep of the Institute and the Journal should come from members and the aircraft industry, the establishment of funds for special purposes or endowments will not only permit the Institute to stimulate aeronautical endeavor but indicate that donors recognize the permanence of its work.

Several suggestions as to possible purposes which are endowable follow:

Institute Endowment Fund to provide income for broadening the activities of the Institute.

Scholarships for young men in technical schools and universities.

Endowments for the Journal of the Aeronautical Sciences which will permit it to print more disclosures of aeronautical advances.

An endowment of an award for contributions to the safety of aircraft.

An endowment for an award for the best aeronautical paper of the year in any aeronautical publication. This should not conflict with the Wright Brothers Medal which is given only for the best paper submitted to the Society of Automotive Engineers.

Contributions toward a building fund for the Institute. The Royal Aeronautical Society is raising a $250,000 fund for a building to house its Library and provide an auditorium for meetings.

Library Fund Endowment to provide the Institute with an adequate library to supplement its index.

Many other worthy causes could be suggested but the above give some indication of the possible uses of such contributions.

*Index.* The Works Progress Administration has continued providing workers to enlarge the Aeronautical Index and Bibliographical Files. The publication of Bibliographies on aeronautics will continue for several months. Approximately seventy-five workers have been engaged in this effort during the past year.

*Finances.* The Treasurer's Report will show the precarious condition of the income of the Institute. This reflects directly in the service rendered by the underpaid and limited staff of the Institute. The amount of overtime and night work required by the staff has now reached a point which is critical.

To publish a magazine and conduct the activities of a scientific society with such a small staff is only possible because of loyal and unselfish work on their part. It is a condition that could be easily remedied if the aircraft companies which do not contribute to the support of the Journal would regard it as a part of their repayment for the many advantages they have received from governmental and private, (*e.g.*, Daniel Guggenheim Fund) contributions to aeronautical research and experimentation.

*Branches.* While several branches have been organized and are enthusiastic in the possibilities of service, they require a service from the Institute that cannot be given without a larger staff.

Your Secretary believes that a society such as the Institute should gradually assume a position occupied by other engineering and scientific societies. No greater opportunity for service exists in the aeronautical field than will come from a strong, well supported technical organization. He is confident that such support will be forthcoming and hopes that his calling attention to the present difficult situation will be regarded as part of his duty.

Once again he expresses his appreciation to members and officers for their confidence and support. The first five years in the history of any organization brings many problems and disappointments. Let us hope that on the foundation that has been laid there will gradually arise a structure of accomplishments which will be a credit to American Aeronautics.

LESTER D. GARDNER

There were 181 legal proxies received and counted by the Tellers, Dr. James H. Kimball, Professor John D. Akerman, and Dr. Stephen J. Zand.

Dr. George W. Lewis, Chairman of the Nominating Committee, put in nomination the following four members for election to the Council for three years and nominated twenty members for the Advisory Committee for one year: For the Council: B. C. Boulton, J. H. Kimball, Arthur Nutt, and Eugene E.

T. P. Wright, newly elected President, I. Ae. S.

Wilson. For the Advisory Board: Vincent Bendix, Lyman J. Briggs, A. B. Cook, J. H. Doolittle, C. L. Egtvedt, Luis de Florez, Jack Frye, W. R. Gregg, Hall L. Hibbard, Alexander Klemin, I. Machlin Laddon, George W. Lewis, Grover Loening, A. E. Raymond, H. J. E. Reid, M. J. Thompson, Gerard F. Vultee, E. P. Warner, O. Westover, and John E. Younger.

As there were no further nominations the Secretary was authorized to cast one vote for the above nominees.

The following members were elected to serve as a nominating committee for 1938: B. C. Boulton (Chairman), W. R. Gregg, E. P. Lesley, Clark B. Millikan, and Eugene E. Wilson.

The following report was presented by Professor John D. Akerman as Chairman of the Student Affairs Committee.

### Report by the Student Affairs Committee

A total of 21 Universities and Colleges have Student Branches of the Institute of the Aeronautical Sciences. The activities of these branches have been reported in monthly issues of the Journal. One of the outstanding services the Institute rendered to the Student Branches was the securing of motion picture films showing the aeronautical laboratories in foreign countries. These films were loaned to Universities and shown to audiences which included not only the student members of that particular institution, but also the general public.

### Recommendations

(1) It is recommended that the Institute secure for the year 1938 the N.A.C.A. 1938 film and some outstanding industrial film on aeronautics for the special use of the Student Branches. This is an inexpensive and convenient way to render help to the Student Branches of the Institute.

(2) Two years ago a recommendation was made that undergraduate papers be accepted for publication in the Journal of the Aeronautical Sciences. Since that time several undergraduate papers have been printed, but no indication has been made that they have been written by undergraduates. To encourage undergraduates to contribute to the Journal, it is recommended that such papers be plainly identified as undergraduate papers.

(3) In each university or technical school where there are Student Branches of mechanical, electrical, and other engineering societies, the national organization offers each year a prize which is awarded to an outstanding undergraduate for excellent scholastic work, or special contribution to that particular branch of engineering. It is quite embarrassing at graduation that all branches of engineering offer recognition to outstanding students in their field, but no award is offered to aeronautical engineering students. Therefore, it is recommended that the Council make special efforts to establish an appropriate prize and a certificate to be awarded to the outstanding student in the aeronautical department or division where a Student Branch of the Institute exists.

(4) Since the Student Branches are the main sources for securing future membership of the Institute, it is recommended that all possible help be extended them so that the students will be properly informed about the importance and advantages obtainable through membership in the Institute.

Dr. J. C. Hunsaker, Editor of the Journal, in discussing the report said that the grade of membership of no author of any paper was ever published in the Journal. He felt that emphasizing the fact that a paper was written by a Student Member would not please the Student Member. He believed that all papers printed in the Journal should be considered on merit alone.

The Secretary read the names of the officers for 1938 elected by the Council as follows:

President—T. P. Wright
Vice-Presidents—Sherman M. Fairchild
J. H. Kindelberger
E. P. Lesley
William Littlewood
George J. Mead
Treasurer—Elmer A. Sperry, Jr.
Secretary—Lester D. Gardner

Dr. Millikan, the retiring president, then called Mr. Wright to take the chair. He expressed his appreciation of the honor of being elected President and the hope that he would be able to contribute to the upbuilding of the Institute as had been done by his distinguished predecessors.

The following resolutions were presented and adopted:

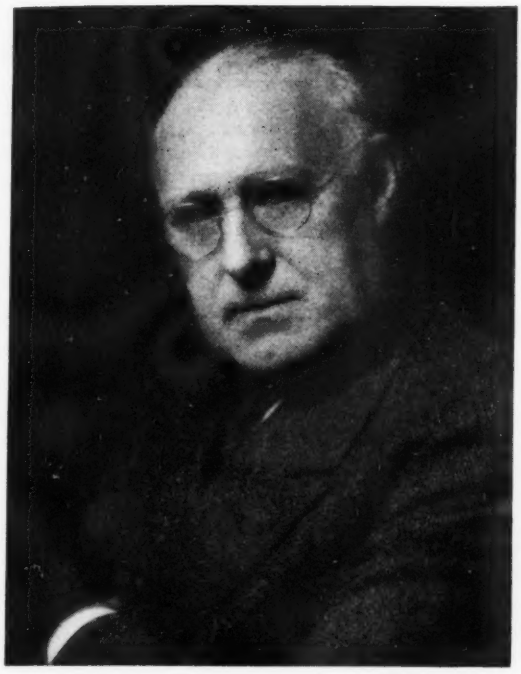
Resolved, that the members of the Institute of the Aeronautical Sciences express their appreciation to Dr. J. C. Hunsaker for his voluntary assistance in editing the Journal of the Aeronautical Sciences and for the prestige he has created for the Institute by the excellent standards of editorial quality that have been maintained.

Sherman M. Fairchild, Vice-President, I. Ae. S.

William Littlewood, Vice-President, I. Ae. S.

J. H. Kindelberger, Vice-President, I. Ae. S.

George J. Mead, Vice-President, I. Ae. S.



Lester D. Gardner, Secretary, I. Ae. S.

E. A. Sperry, Jr., Treasurer, I. Ae. S.

Dr. Hunsaker thanked the members for their commendation. He said that had it not been for the able assistance of George R. Forman of the Institute staff he would not have been able to edit the Journal in the time he was able to give to it. He also expressed his appreciation to the Editorial Board of the Institute and to the staff of the Massachusetts Institute of Technology for the assistance they had given in passing on the quality of the papers for the Journal.

RESOLVED, that the members of the Institute assembled at the Sixth Annual Meeting express their appreciation to the officers and members of committees who have rendered such valuable service in advancing the prestige and reputation of the Institute during the past year.

RESOLVED, that the members of the Institute of the Aeronautical Sciences at the Annual Meeting express their appreciation to Edmund C. Lynch for his generous gift to endow the Institute's annual celebration of the anniversary of the first flights of the Wright Brothers.

RESOLVED, that the members of the Institute of the Aeronautical Sciences at its Annual Meeting express their appreciation to the Materiel Division of the Air Corps for their cooperation in permitting the Journal of the Aeronautical Sciences to reprint parts of the TECHNICAL DATA DIGEST prepared so ably by the staff at Wright Field.

The President expressed the appreciation of the Institute to Columbia University and particularly to Dean George B. Pegram for the use of the Pupin Physics Laboratories and the courtesy of the Men's Faculty Club for the technical meetings, smoker, and lunches during the four-day session. He also thanked the staff of the Institute for their untiring work this winter in organizing the many activities of the Institute.

# Institute Notes

## Technical Sessions of the Sixth Annual Meeting

At the technical sessions of the Sixth Annual Meeting of the Institute, held on January 24, 25, 26, and 27 at the Pupin Physics Laboratories of Columbia University, the following papers were presented. Over five hundred members and guests attended. There were 236 present from places outside the New York area.

Reprints of these papers are not available, and any inquiries regarding papers should be made directly to the author. As space is available in the Journal those papers selected for publication by the Editorial Board of the Journal will be printed.

At the end of the last session, T. P. Wright, President of the Institute, thanked all those who had given papers or taken part in the discussions for their cooperation in making the sessions so interesting.

### MONDAY, JANUARY 24, 1938

9:30 A.M. to 12:30 P.M.—Simultaneous Technical Sessions

#### (1) STRUCTURES

C. J. McCARTHY, Chairman

C. J. WENZINGER and R. T. JONES, National Advisory Committee for Aeronautics, "Design Loads for Tricycle Landing Gears."
JOHN D. AKERMAN and BOYD C. STEPHENS, University of Minnesota, "Polar Diagrams for the Solution of Deflections of Axially Loaded Beams."
W. LAVERN HOWLAND, California Institute of Technology, "Critical Shear Stress in Thin Curved Sheets."
E. REISSNER, Massachusetts Institute of Technology, "Notes on the Structural Analysis of Stressed Skin Wings."
G. M. KLINE, National Bureau of Standards, "Plastics as Structural Materials for Aircraft."
H. V. THADEN, Carnegie-Illinois Steel Corporation, "Stainless Steel in Aircraft."
W. M. MURRAY, Massachusetts Institute of Technology, "New Developments in Seamless Steel Tubing."

#### (2) INSTRUMENTS

CHARLES H. COLVIN, Chairman

VICTOR E. CARBONARA and ALAN G. BINNIE, Kollsman Instrument Company, "Icing of Pitot Static Tubes."
ALEXANDER KLEMIN, New York University, "Theory and Tests of the Mirror Type Pitot."
C. S. DRAPER, WALTER McKAY and W. H. COOK, Massachusetts Institute of Technology, "Northerly Turning Errors of the Magnetic Compass."
JAMES M. COBURN, JR., New York University, "Special Maps for Use with Direction Finding Loops."
C. S. DRAPER and G. V. SCHLIESTETT, Massachusetts Institute of Technology, "Dynamic Errors of the Rate-of-Climb Meter."

#### 2:00 to 5:00 P.M.—AIRPLANE SYMPOSIUM AND DISCUSSION

J. C. HUNSAKER, Chairman

AERODYNAMICS, Clark B. Millikan, California Institute of Technology.
STABILITY AND CONTROL, Otto C. Koppen, Massachusetts Institute of Technology.
STRUCTURES, John E. Younger, University of California.
THE POWER PLANT, Arthur Nutt, Wright Aeronautical Corporation.
TAKE-OFF AND LANDING, George A. Page, St. Louis Division, Curtiss-Wright Corporation
LONG RANGE AIRCRAFT, J. C. Hunsaker, Massachusetts Institute of Technology.

### WEDNESDAY, JANUARY 26, 1938

#### 9:30 A.M. to 12:30 P.M.—AERODYNAMICS

M. J. THOMPSON, Chairman

O. C. KOPPEN, Massachusetts Institute of Technology, "A Method of Determining Aileron Control in the Wind Tunnel."
H. W. SIBERT, University of Cincinnati, "The Effect of the Flexibility of an Airplane Wing on Span Distribution, Load Factor and Dynamic Overstress."
R. H. MILLS, Georgia School of Technology, "Some Accelerated Boundary Layer Profiles."
MICHAEL WATTER, The Glenn L. Martin Company, "Aerodynamic Interference and Interaction from the Designer's Viewpoint."
WALTER CASTLES, JR., Georgia School of Technology, "Selection of the Optimum Aspect Ratio for Cantilever Sailplanes."
FRANK J. MALINA and A. M. O. SMITH, California Institute of Technology, "Flight Analysis of the Sounding Rocket."
J. M. GWINN, JR., Gwinn Aircar Company, "A New Method of Performance Measurement."

#### 2:00 to 5:00 P.M.—AERODYNAMICS

CLARK B. MILLIKAN, Chairman

TH. VON KÁRMÁN and H. S. TSIEN, California Institute of Technology, "Skin Friction of Compressible Fluids."
M. J. THOMPSON, University of Michigan, "Some Aspects of Airfoil Skin Friction."
R. H. SMITH, Massachusetts Institute of Technology, "Laminar Boundary Layer Based on a Minimum Theorem."
MAX M. MUNK, Catholic University of America, "The Triple Origin of Air Forces."
THEODORE THEODORSEN, National Advisory Committee for Aeronautics, "The Fundamental Principles of the N.A.C.A. Cowling."
WM. R. SEARS, California Institute of Technology, "Ground Effect with Special Reference to Pitching Moments."
W. F. GERHARDT, Wayne University, "Some Early Wright Wind Tunnel Tests Interpreted in the Light of Prandtl's Induction Theory."

### TUESDAY, JANUARY 25, 1938

9:30 A.M. to 12:30 P.M.—Simultaneous Technical Sessions

#### (1) ROTARY WING AND LIGHTER-THAN-AIR AIRCRAFT

GEORGE W. LEWIS, Chairman

MONTGOMERY KNIGHT, Georgia School of Technology, "Analytical Comparison of Helicopter and Airplane in Level Flight."
R. H. PREWITT, Kellett Autogiro Corporation, "Possibilities of the Jump-Off Autogiro."
E. BURKE WILFORD, Pennsylvania Aircraft Syndicate, "Control and Performance of Rotary Wing Aircraft."
GERARD P. HERRICK, Herrick Vertaplane Corporation, "Some Aerodynamic Problems in the Design of the Convertible Airplane."
GARLAND FULTON, Bureau of Aeronautics, Navy Department, "Helium Versus Hydrogen for Airships."
A. M. KUETHE, The Daniel Guggenheim Airship Institute, "A Water Tank for Model Tests of the Free Motion of Airships."
JEAN PICCARD, University of Minnesota, "Results of Experiments with, and Possibilities of, the Multiple Balloon Aircraft."

#### (2) METEOROLOGY

W. R. GREGG, Chairman

A. R. STICKLEY, U. S. Weather Bureau, "Some Remarks on the Aircraft Icing Problem."
W. G. BROMBACHER and M. R. HOUSEMAN, National Bureau of Standards, "Stratosphere Balloon Altitude, Barometric and Photogrammetric."
O. C. MAIER and L. E. WOOD, California Institute of Technology, "Modifications of the GALCIT Radio Meteorograph."
H. DIAMOND, W. S. HINMAN, JR., and E. G. LAPHAM, National Bureau of Standards, "Performance Tests of Navy Radio Meteorograph System."
L. T. SAMUELS, U. S. Weather Bureau, "The Weather Bureau's Radio Meteorograph Program."
KARL LANGE, Blue Hill Meteorological Observatory, "The Application of the Harvard Radio Meteorograph for a Study of Icing Conditions."
C.-G. ROSSBY, Massachusetts Institute of Technology, "On the Structure of Warm Anti-Cyclones."

#### 2:00 to 5:00 P.M.—POWER PLANTS AND PROPELLERS

C. F. TAYLOR, Chairman

C. S. DRAPER, Massachusetts Institute of Technology, "Pressure Waves Accompanying Detonation in Internal Combustion Engines."
KENNETH G. MERRIAM and ARTHUR J. STAPLES, Worcester Polytechnic Institute, "Further Investigation of the Aerodynamic Dynamometer."
OSCAR W. SCHEY, National Advisory Committee for Aeronautics, "Measurement of Engine Power at Altitude."
H. M. McCOY, Wright Field, "Full Feathering Propellers."
IVAN H. DRIGGS, The Glenn L. Martin Company, "Simplified Propeller Calculations."

### THURSDAY, JANUARY 27, 1938

#### 9:30 A.M. to 12:30 P.M.—AIR TRANSPORT

D. W. TOMLINSON, Chairman

HARRY G. ARMSTRONG, Wright Field, "Influence of Aviation Medicine on Aircraft Design and Operation."
A. F. BONNALIE, Boeing School of Aeronautics, "Some Economic Factors of Air Line Personnel Training."
L. H. LEONARD, National Advisory Committee for Aeronautics, "Some Problems in the Design of High-Speed Aircraft."
J. J. GREEN, National Research Council, Canada, "Some Special Problems in Take-Off and Landing."
A. B. SCOLES and W. A. SCHOECH, U. S. N. and California Institute of Technology, "Range Calculation for Planes with Continuously Controllable Pitch Propellers."
STARR TRUSCOTT, National Advisory Committee for Aeronautics, "Some Factors Influencing the Form of Large Flying Boat Hulls."

#### 2:00 to 5:00 P.M.—HIGH ALTITUDE FLIGHT

MAJOR CARL F. GREENE, Chairman

W. B. KLEMPERER, Douglas Aircraft Company, "Trends Toward Higher Altitudes in Air Transport."
JOHN E. YOUNGER, University of California, "Structural and Mechanical Problems Involved in Pressure (Supercharged) Cabin Design."
J. W. HEIM, Wright Field, "Physiological Conditions Governing High Altitude Flight."
D. W. TOMLINSON, Transcontinental & Western Air, "Experimental Sub-Stratosphere Flying."
A. W. STEVENS, Wright Field, "Exploring the Stratosphere."
A. H. JOHNSON, Wright Field, "Supercharging a Pressure Cabin Airplane."

### Annual Smoker

This year the attendance at the annual Smoker of the Institute was limited to members. Over two hundred enjoyed the amusing program that had been prepared by Luis de Florez and Jerome Lederer. The courtesies of the Men's Faculty Club of Columbia University were again extended to the Institute through the kindness of Professor George B. Pegram.

Dr. Clark B. Millikan, the retiring president of the Institute, thanked the members for the cooperation he had received during his year of office and introduced the newly elected president, T. P. Wright. Mr. Wright, after expressing his appreciation of the honor of his election, spoke of some of the problems which were still to be solved by the Institute. Charles L. Lawrance then took the chair as toastmaster, and, as at previous dinners entertained by telling some of the stories which only he can relate. After almost disrobing in his realistic description of one incident, he was unanimously urged to tell for the fifth time his famous baron story which has become a fixed feature of these annual smokers.

Dr. Jerome C. Hunsaker surprised Lester D. Gardner by making a presentation speech which related how the Secretary of the Institute had thumbed his way over the leading airlines of the world, and he presented him with a statuette of an upraised arm with wings on each side, the clenched hand of which with an extended thumb symbolized the imploring air traveller who wanted to be invited to take a hop. On the base was inscribed "To Lester D. Gardner with the affectionate regard of the Institute." Major Gardner in accepting the gift admitted being the world's prize sandbag and was evidently so pleased with the surprise presentation that, for once, he was speechless. The trophy was sculptured by Harold Erskine, who lived up to the best traditions of the École des Beaux Arts in the modeling of an amusing idea.

Luis de Florez, with the assistance of Casey Jones, as vacuum tube, then demonstrated his latest invention—"The Compound Regenerative Air Regulations Disintegrator and Decoder." He demonstrated that this device could solve any of the problems confronting the bewildered pilot who becomes confused in the air over some of the new rules. He named the machine "George" and in a few minutes members were laughing at the repartee which ensued between the inventor and the voice which came out of the decoder. Trick regulations were asked and answered without hesitation. The invaluable contribution that had been made to the art of flying was immediately apparent. To show the practicability of the invention he told George to make a landing at Newark Airport. He had just left Cleveland after the N.A.A. convention and was still in a fog. His difficulties in getting into Newark with his private plane between the scheduled airline arrivals were solved by his crashing under a Douglas and telling the control tower operator, who chided him for breaking the regulations, that it did not matter as he was dead. After this enlightening demonstration, George was asked questions about certain well known aeronautical people. He gave the latest news about Dr. J. C. Hunsaker, Dr. Th. von Kármán, Dr. Clark B. Millikan, Lester D. Gardner, Fred D. Fagg, and others. When he was asked what he thought of the aircraft industry his laughter could be heard at ten thousand feet. When his opinion was sought regarding aeronautical engineers he exploded, thus ending the valuable demonstration. Not the least amusing feature of the evening was George's controversy with John Geisse.

The latter part of the evening's program was the showing of a film, "A Visit to Langley Field." This moving picture had been especially prepared for showing at meetings of the Institute through the courtesy of the National Advisory Committee for Aeronautics. The film showed the various wind tunnels and testing apparatus at Langley Field. It will be ready for showing at branches of the Institute in a few weeks. The President thanked Dr. George W. Lewis and the staff at Langley Field for their preparation of the film. He also expressed the appreciation of the Institute to Otis Trowbridge, whose sound engineering made George possible.

Statuette presented to Major Lester D. Gardner, Secretary, I. Ae. S., on the occasion of the Sixth Annual Smoker. The full inscription on the base reads "*To Lester D. Gardner with the affectionate regard of the Institute.*"

### Student Branches

**Carnegie Institute of Technology.** Several meetings of this Student Branch of the Institute were held during the fall. At the first of these, members of the Branch, as well as sophomore and junior non-members interested in aeronautical work, described their experiences during the summer in various fields of aviation. At a meeting held in December, Mr. Zellin of the Pittsburgh office of the Weather Bureau, gave a talk on weather analysis based on study of air mass movements, and exhibited several three-dimensional models to illustrate the nature of the principal movements of air masses. During the fall also, in connection with the Mechanical Engineering seminar at Carnegie Tech, several senior members gave talks before the seminar on various subjects, such as Streamlining, Private Flying, and Superchargers.

**University of Michigan.** A third meeting of this Student Branch was held on Thursday, November 18, in the Natural Science Auditorium at 7:30 p.m. Following routine business motion pictures were shown before the group, consisting of several reels of film loaned by the Army Air Corps showing the flow about various objects placed in an airstream, the flow being made visible by numerous smoke jets. The meeting was adjourned immediately after the showing of the pictures.

The fourth meeting of the year was held on Wednesday evening, December 8, at 7:30 p.m. in the East Engineering Building. At this meeting final plans were made for a trip to Wright Field on Friday and Saturday, December 10 and 11. Forty-three persons went on this trip, and spent the morning at the Waco Aircraft Company and the afternoon and the following day at Wright Field, returning to Ann Arbor Saturday evening.

**Rensselaer Polytechnic Institute.** A number of short business meetings of this Student Branch were held during the month of November. At a regular monthly meeting held in the early part of December, Karl S. Day, Assistant Flight Superintendent of American Airlines, spoke on "The Use of Aviation Instruments." The Radio Beam as well as those instruments essential in a well-equipped airplane were thoroughly discussed with the aid of sketches. An informal discussion followed the lecture.

## Necrology

George Seay Wheat, a Founder Member of the Institute, died at his home in Darien, Connecticut, on December 26, 1937, after an illness of several months.

Mr. Wheat was born in Gallatin, Tennessee, on September 14, 1886, the son of Frank and Clara Seay Wheat. He attended the University of the South, Sewanee, Tenn., and Columbia University.

He started his newspaper career on the Chattanooga Times. In 1910 he came to New York to join the staff of the New York Press. Later he was with the New York Evening Sun and New York Herald where he remained until he joined the Navy in 1917.

During the War, he served as a Lieutenant in the U. S. Naval Reserve Force in the naval intelligence and transport service.

He aided in the establishment of a close censorship for the New York area. Later in the war he was active as an intelligence officer in uncovering much subversive work of spies.

He was one of the organizers of the American Legion and wrote the history of the formation of the Legion.

Following his return to civil life he opened a publicity office in New York and acted for the New York, New Haven and Hartford Railroad and the Wright Aeronautical Corporation of Paterson, New Jersey. He was also one of those who interested Daniel Guggenheim in aviation, an interest which later resulted in the establishment of the Daniel Guggenheim Fund for the Promotion of Aeronautics.

When The Pratt & Whitney Aircraft Company was organized in 1925, Mr. Wheat was appointed one of its officers and was actively engaged in the development of the aviation industry since that time. When the company became a subsidiary of the United Aircraft & Transport Corporation he became vice-president of the latter and with the reorganization of that company into United Aircraft Corporation he retained his vice-presidency and became also a member of the board. He was a director of the Aeronautical Chamber of Commerce of America for many years and was active in its affairs.

He was a member of the National Aeronautic Association; Delta Tau Delta Club; Army and Navy Club (N. Y.); Ox Ridge Hunt, Wee Burn Country (Darien, Connecticut); Army and Navy, Racquet and Tennis (Washington, D. C.), and the Stamford Yacht Club.

Mr. Wheat was the author of "Aeronautical Landing Fields and Airports" and contributed many articles to magazines. He was editor of The Bee Hive, which is published by the United Aircraft Corporation.

On June 12, 1917, he married Ensley Hodgson of New York. He is survived by his wife and three sons.

George Wheat was admired and respected by a wide circle of friends engaged in aeronautics. His intimate knowledge of Naval affairs, particularly those relating to aeronautics, made many friends for him in naval service.

There was no development of national aeronautical policy in which he did not have an interest and his contributions to the betterment of American aviation were many and varied.

## Personnel Opportunities

The Personnel Bureau serves organizations seeking to employ aeronautical specialists as well as individual members. The Bureau has been the means of arranging several very successful connections for members.

Any member or organization may have requirements listed without charge.

*Available*

Executive Mechanical Engineer. Specialty power plants and their cooling, installation, shaft drives, mounting. Wide experience in handling men. Will undertake any responsibility. Available now for new project. Write Box 71, Institute of the Aeronautical Sciences.

Executive Engineer, 6 years experience, age 33. Previously connected with one of the leading aircraft manufacturers in the East. Desires permanent connection requiring broad educational background, experience in aeronautical industry, personnel and business management. Write Box 72, Institute of the Aeronautical Sciences.

## Book Reviews

**Jane's All the World's Aircraft, 1937,** COMPILED AND EDITED by C. G. GREY AND LEONARD BRIDGMAN; Sampson Low, London, 1937; £ 2/2/0.

Each year the writing of a review of this annual becomes more difficult because with each new issue it increases in size and covers a wider field.

With the 1937 volume, which was issued in December, 1937, Charles Grey and Leonard Bridgman have exceeded all past efforts in producing a book which depicts with 605 pictures and describes with comprehensive text the current aircraft and aircraft engines of the world.

The completeness of the section on German aircraft will be a pleasant surprise to many. The section on Russian development will be disappointing although it is well known how difficult it is to secure accurate information as to the extent of the Soviet development.

The seventy-two pages devoted to American aircraft and the twenty-two pages which describe our aircraft engines are as complete as could be desired. The section on Civil aviation in the United States gives useful information regarding the organization of our aviation.

Of course everyone is always greatly interested in the enlightening comment of C. G. Grey in his preface. This year he is even more controversial than usual. When one expresses an opinion of the strength and size of the air forces of the great air powers he is certain to encounter great differences of opinion. Few persons are in such an advantageous position to acquire accurate information and no one can present it more forcefully. What he has to say about our governmental air organization should be carefully considered by those who feel that the United States lags behind other countries in not having an independent and separate air force.

"The United States have also increased their Air Services enormously. Their three independent Services compete for the output of the purely commercial aircraft constructors. The U. S. Army Corps, the U. S. Naval Air Service, and the U. S. Marine Corps, each buys its aeroplanes and its motors separately.

"There are those who claim that the competition between the

three Services results in the production of better and better designs by the constructing firms to meet the higher and higher demands of the competing Services.

"There is much to be said for that argument, because where there is a single Air Force, as in England, Germany, France, and Italy, if a new and valuable idea, possibly in a half-baked form is submitted to the appropriate technical department, it may be turned down flat by a technical officer who has not enough knowledge or intelligence to see that there is the germ of a good idea in it. Or a new type of aeroplane may equally be turned down because the chief of the particular department which has to judge it does not himself like flying that type, or does not like the firm or the individual who has brought it to him. But if the producers of these novelties have a second and even a third technical department to which they can submit their ideas there is always a chance that someting very good may be saved from a premature death. Be that as it may, immense progress has been made in the United States in the design and construction of war machines during 1936–37.

"An interesting psychological point is that the Government of the United States should be building up an immense triple Air Service in spite of the Isolationist policy of the Government, and in spite of the abandonment of the Philippine Islands to the risks and rigours of self-government. The United States have nothing to fear from the Atlantic side, and still less from Canada or from Mexico. The Hawaiian Islands should not be worth the cost of a major war in the Pacific. And yet the United States have one of the biggest and possibly the most efficiently-armed Air Services in the World."

Mr. Grey discusses the Russian, Germany, French, and British air expansion program with equal frankness and interest.

His treatment of the bomber as an air weapon is from the European point of view where distances are not as great and the necessities quite different from those in the United States.

As to flying boats, Mr. Grey is a bit insular. When he claims that the Empire flying boats have "scored over all rivals" he apparently is overlooking the performance and other qualities of the Sikorsky and the Martin flying boats. No one will deny the excellence of Short Brothers fine aircraft, but when derogatory comparisons are made with the products of other countries a word of mild protest is in order.

Not the least serviceable part of the book will be the many pictures of aerodrome buildings in many parts of the world. The United States has taken pride in its great airport development but when we observe the huge airport buildings and hangars that have been built in other countries, particularly with the proposed buildings at Templehof aerodrome in Berlin, we will have to concentrate on a building program if we are to keep abreast of foreign facilities for air travellers.

Again we venture to express the gratitude of American readers for the great amount of effort which Mr. Grey, Mr. Bridgman, Mrs. McAlery, and others put into this compilation which affords all aeronautical specialists their most useful reference work.

LESTER D. GARDNER

**Synoptic and Aeronautical Meteorology,** by HORACE R. BYERS; McGraw-Hill Book Company, New York, 1937; 279 pages, illustrated, $3.50.

Here is a much needed book including just the information and theory of meteorology and air-mass analysis required by the practical forecaster or aviator, or, in fact, by anyone wishing a review of modern meteorology exclusive of observational technique. It is not a trade-school type of textbook, but a true meteorology in which the discussion is built around the physical causes. Formulas are introduced where necessary to an understanding of the details, but derivations are avoided, and the reader is referred to sources. The discussion is clear, not too technical, interesting, conservative, and remarkably free from questionable statements.

Dr. Byers has divided his text essentially into three parts: the fundamental principles of meteorology, synoptic meteorology (air-mass analysis), and aeronautical meteorology. However, the principles extend all the way through the book; the synoptics spill over into the aeronautical portion, and the aeronautical applications are by no means confined to the chapters written particularly for aviators.

The fundamental principles of meteorology are treated in the first six chapters and in three of the last six—the group of particular interest to aviators. The main topics are: radiation and the temperature distribution in the atmosphere; stability, instability, and vertical motions; air masses—their characteristics and modifications; the general circulation; the secondary circulations—cyclones and anticyclones; changes in air masses with lifting; condensation and precipitation; the thunderstorm, the tornado, and waterspout; and atmospheric turbulence and the wind structure near the surface of the earth.

Synoptic meteorology is covered, with remarkable conciseness for its comprehensive content and completeness of instruction, in but three chapters, totalling 55 pages: the air masses of North America; air-mass analysis on the synoptic chart; and weather forecasting. A whole chapter on cloud forms as aids in forecasting instead of only a few incidental references, would probably have been appreciated by the air-minded fraternity that will be the chief users of this book.

Among the special chapters included for aviators are a comprehensive discussion of fog, and shorter treatments on the formation of ice on aircraft, and on dust storms. These are all very well discussed, the fog not only genetically but also geographically. The chapters of general meteorological interest on condensation and precipitation, the thunderstorm, etc., and atmospheric turbulence, etc., already mentioned, are also placed in this group of topics of particular aeronautical interest.

The exceptional merit of Dr. Byers' book for the purpose intended will place this text not only in the hands of all students of synoptic and aeronautical meteorology, but also on the desks of all meteorologists anywhere, or amateurs, not necessarily interested in aviation, will find this work of interest and valuable for reference. Though requiring thoughtful attention, Dr. Byers' text leaves the reader deeply satisfied with a new understanding of the intricacies of atmospheric processes.

CHARLES F. BROOKS
Blue Hill Observatory

# AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

## Aerodynamics

**What Is the Nature of the Feathers of the Bird.** A. Bertin. Principle of reaction and use of air currents; analogy to the acetylene burner; structure of the natural surfaces similar to turbine blades; hypothesis of F. Houssay regarding the resistance of air to the model of the bird; aerodynamic, geometric, physiological and mechanical questions involved in muscular flight; the "insect" solution as the only possible one for the manually operated aircraft; and natural and classical aerodynamics. Les Ailes, December 16, 1937, pages 7–8, 4 illus.

**Turbulence.** T. von Kármán. Taylor's definition of turbulence; mechanism of diffusion; examples of turbulent exchange; cases where turbulence works against and for the aeronautical engineer; turbulence at its birth, in its prime, and in decay; and basic concepts of the statistical theory. Journal Royal Aeronautical Soc., December, 1937, pages 1109–1142, 21 illus., 1 table, 42 equations.

## Aircraft Design

**The Air Drag of Hulls.**—L. P. Coombs and K. W. Clark. In the Royal Aircraft Establishment tests described, an idealized form of hull was used as a standard and then systematically varied in shape to cover all changes likely to occur in practice. Air drag and water characteristics were found. Article covers: development of the narrow beam hull; effect of reduced beam; design of the basic hull; comparison of hulls, length of take-off and beam; variation of air drag with beam; effect of increased depth of hull; drag of projecting and sharp chines; comparison of hull drag with that of a streamline form; effect of sweeping the after body up or down; vee bottom made more obtuse or more acute; effect of hollowing the vee of the planing bottom; and drag of lateral stabilizers. Long article. Aircraft Engineering, December, 1937, pages 315–321 and 328, 21 illus., 3 tables.

**The Natural Limits to Human Flight.** H. E. Wimperis. Natural limits to high speeds and to power of maneuver (limitations due to accelerations encountered during flight and to endurance of the human body and the airplane), and the extreme altitude and range of flight. Journal Royal Aeronautical Soc., December, 1937, pages 1095–1107, 5 illus.

**The Outlook.** Growing complexity of the modern military airplane and question of whether such complexity is altogether necessary. Editorial recommending simplification of primary structure to speed up production, simplification of plumbing and other equipment, standardization in the placing of controls and instruments, and more attention to the problems of comfort for crews. Flight, December 9, 1937, pages 567–568.

**Balancing of Flaps.** J. E. Serby. Aerodynamic and mechanical methods of reducing the effort required in the operation of flaps. Hinge moment data on the split or Schrenk flap; Youngman double-link flap; Zap flap; reverse-motion balance including the Miles-Irving and the Irving articulated balances; set-back hinge or arc-type flaps; rotating-arc Gouge flap; and retractable arc flap achieving a high degree of balance.

Need for balanced flaps is discussed in an editorial and hydraulic pumps for airplanes described in a second article. Aircraft Engineering, November, 1937, pages 292–294 and 286, 8 illus.

**Design Problems in Aircraft.** Ways of increasing performance, design of flotation gear, tailless construction for high-speed airplane, propellers for high-speed airplanes, and wind-tunnel results on airfoil tests. Short abstracts from DVL 25-Jahrfeier Anlass.-V.D.I., November 6, 1937, pages 1317–1318, 1 illus.

**Fighter versus Bomber.** Authors of Air Strategy. Twin-engined destroyer fighter, high-performance bomber, scout, and "fighter leader," and single-seater fighter designs are proposed for the Independent Air Force. Required characteristics, power plant, performance, armament, and armor for these aircraft are given in a table, and drawings show general design and equipment layout. Armament of all Independent Air Force fighters is of the axial restricted field type.

Douhet and Rougeron doctrines are said to "virtually ignore active air defence." These doctrines, universal and multiple-purpose aircraft, bomber performance compared with that of the fighter, and single- and twin-engined aircraft are also discussed. R.A.F. Quarterly, October, 1937, pages 329–350, 9 illus., 3 tables, 3 equations.

**Formation of Ice on Aircraft.** T. A. Aspell. Factors inherent in the design of wings which determine the accretion of ice on ailerons, and a new Goodrich deicer having a phrenite-graphite outer surface. Results of Goodrich icing tests on a Douglas transport wing, complete with ailerons are described in detail and design recommendations made. Wings were fitted with removable blocks at the trailing edge of the wing and at the leading edge of the aileron, so that various aileron arrangements could be tested in the same setup. Reference is made to further icing tests with a fillet strip acting as closure for the aileron cutout slot, and to tests on all movable control surfaces.

The new Goodrich deicer has an outer surface designed to bleed off electrostatic charges and to protect rubber deicers from damaging effects of engine oil. Results of flight tests with the deicer are described. Aero Digest, December, 1937, pages 23, 96, 4 illus.

**High Wing Loading and Some of Its Problems from the Pilot's Point of View.** Squadron Leader H. P. Fraser. Problems arising from high performance and increased wing loading in regard to take-off, irreversible aileron control, approach, flattening out, touching down, and recommendations for their possible solutions. It is desirable to have self-centering aileron controls on airplanes carrying fixed front guns and on such airplanes it seems possible that ailerons both self-centering and irreversible may be fitted. The nose wheel alighting gear should be fitted to all future designs. Royal Aeronautical Soc., Preprint for Meeting, December 2, 1937 ,22 pages, 14 illus.

**The Modern Junkers Wing.** A. W. Quick. Aerodynamic development of the Ju-86 wing with particular reference to lateral stability about the longitudinal axis or "wing dropping." Influence on wing dropping of lift distribution and characteristics of the wing sections at every point on the span, calculations on the Ju-86 which formed the basis for the shape of the second wing, and results of wind-tunnel flight tests are discussed.

Editorial discusses the puzzling results with two Junkers wings of different plan. Results are compared with those given in a previous article by Irving on stalling characteristics of wings with various forms of taper. Translated from 1936 Yearbook of the Lilienthal-Gesellschaft fuer Luftfahrtforschung. Aircraft Engineering, November, 1937, pages 287–291 and 285–286, 12 illus.

**Modern Tendencies.** Survey of present practice in aerodynamic and structural design of British military and civil aircraft. Types of construction employed in the various large aircraft, complete disappearance of the large biplane, ascendancy of the twin-engined type, multigun turrets, and adherence to small caliber guns are discussed. Problems in the disposition of free guns on the modern bomber are also referred to. No small-bore British cannon has yet been announced. Flight, November 25, 1937, pages 502–504, 14 illus.

**Protection.** Problems in the protection of aircraft and crew against shell splinters and against projectiles fired from hostile aircraft. Advantages of the single-engined single-seater fighter over the big air cruiser in regard to protection, the protection of the vital parts of aircraft against splinters of shells fired by anti-aircraft guns, and question of whether the feasibility of protection warrants its adoption. From "L'Aviation Bombardment," C. Rougeron. R.A.F. Quarterly, October, 1937, pages 351–356.

**Radius of Curvature in the Correct Turn.** Capt. S. G. Santangelo. Expressions of aerodynamic values in the correct controlled turn are derived for a certain trim of the airplane and in functions of radius of the evolution. Effects of wing load, superficial power, and altitude are demonstrated and the uncontrolled turn is also considered. A general graph is given for determining immediately the inherent value for the correct turn. L'Aerotecnica, August–September, 1937, pages 751–761, 7 illus., 13 equations.

**Simplifying Approach Technique.** Abstract of Royal Aeronautical Society paper by Squadron Leader H. P. Fraser, and the interesting discussion following. Flight, December 9, 1937, pages 588–589, 2 illus. Aeroplane, December 8, 1937, pages 709–710, 1 illus.

**The Sinking Speed of Aeroplanes.** B. Lundberg. Swedish suggestion of an alternative to horsepower required for use in performance calculations. Sinking speed, object of the complete analysis given, is based on the general formula for total drag coefficient. "Fixed" induced drag is introduced instead of the common geometrical quantities "effective span" or "effective aspect ratio." Calculations cover sinking speed in a steady glide, sinking speed with engine on, drag equation, parasite and induced sinking speed, best glide ratio, and lowest sinking speed. To be continued. Aircraft Engineering, December, 1937, pages 322–324, 328, 2 illus., 2 tables, 52 equations.

**Technical Notes.** Additional information on the Armella-Senemaud slotted ailerons. Maximum Cz of the profile of the base is multiplied by 1.9 for deflection of 30° only. Brief reference. Les Ailes, December 16, 1937, page 8.

**Technical Notes.** Flying wing designed by M. Filleul. In the central region limited by two box ribs carrying tail fins and rudders, the planes front and rear are separated in such a fashion as to constitute an intermediary arrangement between the "optimum biplane" of the Institut de Saint Cyr and the tandem. Effect of the slots renders efficacious the tail flaps mounted on the central rear part of the trailing edge of the wing. Short note. Les Ailes, August 19, 1937, 1 illus.

## Stress Analysis and Structures

**The Analysis of Elastic Structures.** E. H. Bateman. Deformation energy method and method of Remainder Distribution recently developed by the author. British Association paper. Engineering, December 10, 1937, pages 669–671, 5 illus., 3 tables, many equations.

**On Aircraft Construction.** C. G. Grey. Revival of timber; metal and mass production; designing for production; machine tools; cooperation between designers and works staff; question of metal plus timber rather than metal versus timber; and need for more "shadowing" of the steel industry. Mr. Grey's introduction to this Special Aircraft Construction Issue. Aeroplane, December 15, 1937, pages 726–727.

**The Behavior of Rectangular Plates under Concentrated Load.** R. G. Sturm and R. L. Moore. Experimental and analytical research on flat plates under concentrated normal loads conducted at the Aluminum Research Laboratories. Plates ranged from 1/8 to 1 in. thickness and were loaded on spans of from 48 to 384 times the thickness. Effect of degree of load concentraton, types of edge support, and position of load upon stresses and deflection were studied as well as cases of bending alone and combined bending and direct stress. Analytical work refers to existing general analysis of the flat-plate problem from which design formulas are derived. Journal Applied Mechanics, June, 1937, pages A75–A85, 12 illus., 6 tables, 8 equations.

**Buckling of Compressed Rectangular Plates with Built-In Edges.** J. L. Maulbetsch. Two approximate methods for determining buckling load of these plates. The Taylor-Trefftz method leads to a value smaller than the exact value of the buckling load and the energy method developed by Timoshenko gives a larger value. By use of both methods an approximate solution is obtained, the maximum error of which is known. Journal Applied Mechanics, June, 1937, pages A59–A62, 3 illus., 1 table, 21 equations.

**The Case for Wood.** B. Jablonsky. "Improved wood" is built up of a number of thin veneers, their thickness being in accordance with required strength and density. Two methods of improving wood, and "reinforced wood" made by the Heine process for propeller blades and spars are described. Improvements in mechanical and other properties obtained by impregnation with synthetic resins, and advantages of these materials for aircraft construction are considered. Flight, December 16, 1937, page 604a, 604d, 605, 4 illus.

**Deflection of Beams of Varying Cross Section.** M. Hetenyi. Effect of variation of cross section on shape of the deflection curve can be represented by a properly chosen force system acting on a beam of uniform cross section. No approximation is involved in this substitution. Method is described. Journal Applied Mechanics, June, 1937, pages A49–A52, 6 illus. 13 equations.

**Metal Construction of Aeroplanes.** A. F. Bennell. Particular requirements of the fuselage, main planes, main-plane control surfaces, and tail unit are considered in detail for each particular type of construction. Changes in methods of fabrication which have closely followed development in airplane forms and introduction of improved materials are pointed out. Structure arrangement of monocoque fuselage construction and methods used to fabricate this unit are discussed and detail manufacture of spars described. Author is with the Bristol Aeroplane Company and refers to the construction of the Blenheim bomber. Aeroplane, December 15, 1937, pages 743–748, 10 illus.

**Pin-Jointed Struts.** L. H. Sumanadasa. Simplified method for solving the following equation for the permissible stress:

$$p = p_y/[1+(d\delta/2k^2)\ \sec\ \{(l/2k)\sqrt{(p/E)}\}]$$

Journal Royal Aeronautical Soc., December, 1937, pages 1162–1164, 2 tables, 13 equations.

**Plastics in Aircraft.** M. Langley. Thermoplastic materials such as celluloid, Rhodoid, or Perspex and their present uses in aircraft. Possibilities in further development, difficulties to be overcome, and use of wood improved by addition of synthetic resin are considered. The author points out the value of alternative wooden wings designed for some military all-metal types at present in large production for the R.A.F. in cases of emergencies where shortage of skilled metal workers and metal supplies arises. Author is Chief Designer, British Aircraft Manufacturing Company. Aeroplane, December, 15, 1937, pages 749–750, 7 illus.

**Combined Stresses.** H. Parkinson. Working charts given for combined stress factors and selection of suitable members cover the design of circular tubes, bolts, and shafts subjected to combined stresses. Aircraft Engineering, November, 1937, pages 308–309, 5 illus., 4 equations.

**Solving Space Structures Graphically.** E. Moness. Method for solving any statically determinate space structure graphically. Systematic procedure has been worked out to make its application simple and mechanical and to permit anyone to check its correctness. To be continued. Aviation, December, 1937, pages 30–31, 78, 81, 7 illus.

**Wood Construction of Aeroplanes.** A. H. Tiltman. Relative merits of wood and metal construction as they appear to both designer and operator. Compressed wood construction with reference to the novel type of construction in the DeHavilland Albatross fuselage; composite construction for prototypes; developments in cements for wooden construction; compressed wood for controllable-pitch propellers; and the wooden stressed-skin construction used in the DeHavilland Comet. Graphs show strength-weight ratios for Jablo improved laminated wood of varying densities, and comparative strength-weight ratios for laminated wood, spruce, dural, and steel. Aeroplane, December 15, 1937, pages 738–742, 11 illus.

## Aircraft Accessories

**Hydraulic Pumps for Aeroplanes.** F. Nixon. Detailed descriptions for the following: Reciprocating pumps—Rotoplunge hydraulic, Messier hydraulic, Olaer hydraulic, and Vickers high-pressure oil pumps; positive rotary displacement pumps—Dowty engine-driven power and Lockheed engine-driven fluid pumps, integral auxiliary equipment, and Pesco high-pressure oil, Rotax-Eclipse hydraulic, Northern oil, and Tecalemit high-pressure oil pumps. Screw-viscosity pumps—Mirrlees-Imo pump.

Lines of future development are discussed and design requirements are outlined in regard to performance, weight, compactness, fluid tightness, nonpulsating delivery, reversibility, controllability, flexibility of design, safety, ability to prime, and standardization of flanges and drives. Aircraft Engineering, November, 1937, pages 295–303, 23 illus., 1 table.

**Pneumatic Shock Absorbers for Aircraft and Automobiles.** H. Irmer. Drawings of the VDM-Faudi pneumatic, and oleo-pneumatic aircraft shock absorbers are included in an article discussing the application to automobiles of pneumatic shock absorbers designed for aircraft. V.D.I., October 9, 1937, pages 1182–1186, 20 illus.

**Steel-Cleated Aircraft Tires.** Steel cleats are imbedded in the multivaned tread of the General streamlined airplane tires with which the U. S. Army Air Corps has been experimenting. Brief reference. Aero Digest, December, 1937, page 89, 1 illus.

## Aircraft Performance Testing

**"Here Goes Nothing!"** Edmund T. Allen. Three stages which have been covered in the development of flight testing with special discussion of progress in spinning, controllability, and flutter. Aviation, December, 1937, pages 24–25, 73, 1 illus.

## Aircraft

**Milan Shots.** Photographs of new aircraft exhibited at the Milan show with brief notes on each, giving specifications. Aviation, December, 1937, pages 26–27, 10 illus.

**Military Aircraft at the Second International Air Show at Milan.** G. W. Feuchter. Short descriptions. Luftwehr, October–November, 1937, pages 459–471, 29 illus.

**War Aircraft Illustrated 1914–18.** G. Muir. Details of the Maurice Farman Shorthorn, Avro 504K, B.E. 2c, B.E. 2e, DeHavilland 2, DeHavilland 10 Amiens, Sopwith Cuckoo, and Curtiss H12 flying boat. R.A.F. Quarterly, Supplement, July, 1937, 8 illus.

**Speed Record over 100 Km. Has Been Raised to 554.350 Km./Hr. by Pilot Furio Niclot.** Records made by Niclot in a Breda 88 over 1000 km. with 500 and 1000 kg. load at a speed exceeding 524 km./hr., and the three German records made on November 23 with a Heinkel 111–1 are discussed. Comments of L. Bréguet, Wiedemann-Goiran, and R. Couzinet regarding the Italian and German records are included. Les Ailes, December 16, 1937, pages 5, 7.

**High-Altitude Flight.** A. Weise. Details of record-breaking high-altitude airplanes including the Bristol 138, the Potez 50-A2 (Gnôme Rhône 14-Krsd 14-cylinder 2-row radial engine) in which M. Hilsz reached 14,310 meters in June, and the Caproni 161 (Piaggio P XI R.C. 72 14-cylinder double-row engine) which reached 15,655 meters on May 7. Technical evaluation of the most recent record flights, possibilities for improving the power plants and airplane performance, and the ideal comparison are considered. A Junkers high-altitude experimental airplane with pressure cabin is illustrated and referred to. V.D.I., October 9, 1937, pages 1177–1181, 8 illus.

### Canada

**Foreign News in Brief.** Fairchild Sekani, first twin-engined airliner to be designed and built in Canada, is powered by two 420-hp. Pratt and Whitney engines, carries a 2500-lb. payload, and cruises at 161 m.p.h. at 5000 ft. Brief note and brief reference to 18 Bristol Blenheim coastal reconnaissance twin-engined aircraft to be built by Fairchild; Link trainers being built in Canada for the British Air Ministry; three Grumman fighters being built for the Nicaraguan Air Force by the Canadian Car and Foundry; and 20 more flying boats bought from Canadian Vickers. Aero Digest, December, 1937, page 112.

### France

**Air France Gives up the Farman 40-Passenger.** Air France will not take delivery of the four-engined Farman 224. The Armée de l'Air has need for troop transports and will probably receive these aircraft while Air France will use Dewoitine D-338s instead of them. Brief reference. Les Ailes, November 11, 1937, page 15.

**66 Tons at 420 Km./H.** Unusual Latécoère Laté-631 six-engined flying boat of 57-meter wing span and 9000 total hp. will be able to transport between Europe and the United States 20 passengers, a crew of eight, and 3 tons of freight at an average speed of 350 km./hr. A few details of unusual Latécoère project. Les Ailes, December 16, 1937, page 8, 2 illus.

Photograph. Flight, December 23, 1937, page 633.

**Airplanes in Test.** Very brief references to military airplanes undergoing tests. First issue—Caudron-Renault C-710 light pursuit (Renault 12-cylinder inverted 450-hp. engine, estimated maximum speed 440 km./hr. at 5000 meters). Dive bombing testing the Gourdou 521 (Gnôme Rhône K-7 500-hp. engine) diving from 3000 meters without passing 320 km./hr. due to aerodynamic brakes, and the Loire-Nieuport 140 also equipped with aerodynamic brakes, reconstructed as a single-seater, and utilizing a reversible-pitch propeller for reducing diving speed. LeO-45 high-speed bomber.

Second issue—Amiot 340 (two Gnôme Rhône 14-No. 950-hp. engines). LeO-45 bomber. Marcel Bloch 150 pursuit (Gnôme Rhône K-14 950 hp. engine, estimated total weight 2200 kg., maximum estimated speed 500 km./hr. at 3700 meters, range 900 km. at 450 km./hr. cruising speed). Marcel Bloch 203 (two Clerget 14-F 500-hp. heavy-oil engines). Morane Saulnier 405 C-1 prototype. Les Ailes, December 9 and 16, 1937, pages 6 and 15.

**Amiot 370 Hispano Long-Range Airplane.** With two Hispano-Suiza 12V liquid-cooled engines the Amiot should attain a maximum speed of 475 km./hr. at 4000 meters. Brief note. Les Ailes, August 5, 1937, page 8, 1 illus.

**The Codos South American Flight.** Four-engined Farman 2231 was flown by P. Codos from Le Bourget to Santiago, Chile, in a study of operating conditions over the South Atlantic and South American lines of the Air France system. The 7862-mile trip was covered in 58 hr. 41 min. elapsed time and 51 hr. 45 min. flying time. Four Hispano-Suiza 12 Xirs water-cooled moderately-supercharged engines are mounted in pairs below the wing close to the fuselage. Top speed is 216 m.p.h. at 7850 ft. A few additional details of flight and airplane. Flight, December 9, 1937, page 577, 1 illus.

**A Field Day for Prototypes.** New Lioré 45 bomber was technically the most interesting airplane in the recent demonstration of French military aircraft at Villacoublay. The Lioré 45 has two 1100-hp. Hispano radials, an all-up weight of 23,500 lb., top speed of 290 m.p.h. at 16,500 ft. and range of 1600 miles, and has been dived at about 370 m.p.h.

Other airplanes referred to include: Caudron-Renault light single-seater fighter (new Renault 12-RI inverted aircooled vee engine, maximum speed 273 m.p.h.). Morane Saulnier M.S.405 and the 300-m.p.h. Nieuport 161 (both fitted with latest type of Hispano Y engine). Bloch 150 single-seater (1000-hp. Gnôme-Rhône 14 No. radial). Marcel Bloch 131 medium bomber (Gnôme-Rhône 14 Ns, top speed 240 m.p.h.). Marcel Bloch 133 medium bomber (Hispano two-rows of 1100 hp. giving 25 m.p.h. increase in top speed). Potez 63 twin-engined fighter or fighter command (two small-diameter Gnome-Rhone 14 Ms, top speed around 290 m.p.h.). Potez 56–6 light observation monoplane (two Potez radials and underslung observation car). Hanriot 230 trainer (unorthodox high-wing monoplane, two Salmson inline inverted 6-cylinder aircooled sixes, top speed 160 m.p.h.). Armament is referred to in some cases.

Trends indicated more careful cowling of aircooled engines, less insistence on wide fields of fire from free armament on high-speed bombers, better outlook from pilot's cockpits, and more careful fairing of wing-mounted cannons.

Same issue also contains a brief note giving other details of the Lioré et Olivier LeO-45 high-speed bomber. Flight, December 9, 1937, pages 580b-580c and 586, 7 illus.

**The Four Winds.** French dive bombers, notably the cranked-wing Nieuport converted single seater, are being fitted with reversible-pitch propellers to keep down the speed for dive-bombing purposes. Brief reference. Flight, December 16, 1937, page 601.

**Hanriot Three-Seater Light Defensive Fighter.** A. Frachet. Hanriot H-220, first French military airplane to have a maximum speed exceeding 500 km./hr. With two Gnôme Rhône M-14 650-hp. engines it climbs to 8000 meters in 13 minutes and maintains a height of 7000 meters with one engine off. Maximum speed is 505 km./hr. Loaded at 160 kg./sq. meter (total weight loaded 3000 kg.) the airplane has a minimum speed of 130 km./hr. Long description, characteristics and performance. Les Ailes, Dec. 9, 1937, page 9, 2 illus., 2 tables (1 illus. on page 1).

**A Mediterranean Prototype.** During tests the new 26-passenger Lioré et Olivier flying boat for Air France Mediterranean services left the water in 33 seconds carrying a total load of 44,000 lb. Top speed is 200 m.p.h. and cruising 165. Machine has a metal hull and a high wing in wood. Four Hispano 12X engines are placed above the wing on metal supports and arranged tandem fashion in pairs side by side. Brief reference. Flight, December 9, 1937, page 583.

**Mulo AM-20.** A. Frachet. Single-seater for training in aerobatics is equipped with a Train 60-hp. engine and has a maximum speed of 215 km./hr. Long description. Les Ailes, August 19, 1937, page 8, 2 illus., 2 tables.

**Possibilities of the Flying Wing.** Flight of the A.V.-10 flying wing designed by C. Fauvel. Brief note referring also to three new airplanes of the flying-wing type being tested in Russia. Les Ailes, December 9, 1937, page 13, 1 illus.

**Airplanes in Test.** First issue—Morane-Saulnier M.S.350 single-seater for training in aerobatics. Louis Bréguet 462 Vultur bomber (two Gnôme Rhône 14-No. engines of 1900-hp.). Marcel-Bloch 131 No. 2 (two Gnôme Rhône K-14 of 2000-hp.). Loire-Nieuport N-161 No. 2 pursuit (Hispano-Suiza 12 Ycrs 860-hp. "moteur-cannon"). Loire-Nieuport 20 three-place pursuit command (two Gnôme-Rhône 14-Mars). Farman F.222–2 bomber (four Gnôme Rhône engines), and the F-223 high-speed bomber (four Hispano-Suiza 14-AA engines).

Second issue—Caudron-Renault C-690 pursuit trainer (supercharged Renault 6-Q.2 engine developing 220 hp. at 2000 meters). Morane-Saulnier 405 C-1 prototype of the single-seater pursuits being constructed in series for the Armée de l'Air. Amiot 340 bomber. Potez 631 three-seater (two Gnôme Rhône 14-Mars) pursuit command, first of which will be equipped with two new Hispano-Suiza 14-AB engines to give it a speed of 520 km./hr. Caudron-Renault C-720 for acrobatic training (Renault 4-Pei 140-hp. engine). Brief references only to these airplanes in test. Les Ailes, November 11 and 18, 1937, pages 15 and 15.

**Kellner-Béchereau.** Two-seater E.C.-3 light airplane, one of three winners of the Société du Duralumin contest. Photographs and a few details. Les Ailes, November 18, 1937, page 12, 4 illus.

GERMANY

**Hamburg Ha 139 Long-Distance Seaplane.** Seaplane designed for North Atlantic services is powered by four Junkers Jumo 205C 600-hp. engines and has a top speed of 304 km.–hr. and range of 5000 km. at a cruising speed of 250 km./hr. Long description, characteristics, performance, and photographs showing construction. V.D.I., October 9, 1937, pages 1194–1196, 8 illus., 1 table.

**Germany's Latest.** Focke-Wulf Condor all-metal four-engined low-wing monoplane. Powered with four B.M.W.132G 720-hp. engines, the airplane is capable of making more than 200 m.p.h. cruising speed when carrying a crew of four and 26 passengers. If fitted with more powerful engines of the same make, the airplane will have a maximum speed of 267 m.p.h. With full payload and at 205-m.p.h. cruising speed, fuel consumption is 7 liters per passenger per 100 km. The Condor will fly at 125 m.p.h. with two engines stopped. Description, characteristics, performance. Flight, December 23, 1937, pages 624a–624b, 5 illus., 2 tables.

**Junkers Ju-90 Transport Airplane.** A. Frachet. All-metal monoplane having four Jumo 211 1100-hp. engines and arranged to carry 40 passengers. For a cruising speed of 350 km./hr. its range is 2000/3000 km. according to payload. Maximum speed is 410 km./hr. Long description, characteristics, performance. Les Ailes December 16, 1937, page 9, 3 illus., 2 tables.

**Shipping it Green.** Latest Dornier naval flying boat supplied to German and Dutch governments. Those for the latter are powered by Pegasus or Cyclone engines. Top speed is 212 m.p.h. Photograph only of flying boat taken during rough weather trials. Flight, December 16, 1937, page 601, 1 illus.

**Technical Notes.** Flight tests have been carried out by Dornier on a seaplane equipped with steam generators and turbines, according to rumor. Brief reference. Les Ailes, August 19, 1937, page 9.

Dornier has constructed a trimotored observation seaplane derived from his transatlantic Do.18. Maximum speed should be about 340 km./hr. Brief reference. Les Ailes, December 16, 1937, page 8.

**Tests of the New Dornier Do-19.** Four-engined Dornier Do-19 of 18,500 kg. is powered by four Bramo 322 H-2 air-cooled engines giving a total of 2600 hp. and has a maximum speed of 320 km./hr. Short description and comparison with the Bloch 160. Les Ailes, August 12, 1937, page 9, 2 illus., 1 table.

GREAT BRITAIN

**For Light Reconnaissance.** Fairey Seafox lightly-loaded lightly-armed catapultable floatplanes used in the Naval services are designed to be operated from the smaller type of naval catapult. They are expected to be able to land safely in quite appalling seas and must withstand the blast of naval guns and effects of prolonged exposure to sea water and salt air. Due to compactness when folded, three may be carried on an average-sized cruiser. A Napier Rapier VI medium-supercharged 16-cylinder air-cooled H engine develops a maximum of 380/395 hp. at 4000 r.p.m. at 6000 ft. Maximum speed at 5860 ft. is 124 m.p.h. and range 440 miles. Very long well-illustrated description of construction, easy maintenance features, armament characteristics and performance. Flight, December 9, 1937, pages 570–574, 20 illus. Aeroplane, December 8, 1937, pages 706–708, 7 illus. 1 table.

**British Civil Aircraft: The Smaller.** Characteristics and performance of 28 aircraft carrying less than six passengers. Table and description of products of 19 companies. Flight, November 25, 1937, pages 515–522, 23 illus., 1 table.

**British Commercial Aircraft.** Review of 15 types having seating accommodation for more than five passengers. Main aerodynamic and structural features and numerical data are given for products of the Airspeed, Armstrong-Whitworth, C-W, DeHavilland, General Aircraft, Phillips and Powis, Pobjoy, and Short firms. Flight, November 25, 1937, pages 506–511, 14 illus.

**British Military Aircraft.** Current types of fighters, light and medium bombers, heavy bombers and bomber-transports, general reconnaissance, army-cooperation, general-purpose, training, target, marine and coast defense aircraft are reviewed.

Superlative performance of the new fighters and bombers, aerodynamic and structural advances, armament, weights, and performance are pointed out. The Supermarine Spitfire, Hawker Henley, Vickers Wellesley and others are illustrated, and cutaway drawings of the Gloster Gladiator, Bristol Blenheim, Fairey Battle, and Avro Anson show location of equipment. Flight, November 25, 1937, pages 514a–514*l*, 39 illus., 1 table.

**Dimensions, Weights, Performance Figures of British Aircraft of 1937.** Data on 87 British aircraft including 46 military aircraft. In the case of the Supermarine Spitfire and some other military aircraft, parts of the data were not released. A second article gives photographs and three drawings for 74 aircraft. Aeroplane, November 24, 1937, pages 618–619 and 621–640 many illus., 1 table.

**Prospects and Potentialities.** New types of British aircraft which are likely to blossom out during the coming year. Brief references to aircraft being built by 14 companies. Aeroplane, November 24, 1937, page 633.

**The Percival Twins.** Q4 and Q6 light twin-engined monoplanes for private owner, airline feeder work and military training. Former is powered with two Gipsy Major II 140 hp. engines and has a top speed of 170 m.p.h. and the latter is powered with two Gipsy Six II 205-hp. engines and has a top speed of 195 m.p.h. Long description of construction, characteristics and performance. Flight, December 16, 1937, pages 596–598, 595, 8 illus.

Long description. Aeroplane, December 22, 1937, pages 785–788, 11 illus.

**Side-by-Side Simplicity.** Knight two-seater cabin monoplane of wooden construction is the first product of Deekay Aircraft Corporation which was formed to explore, among other things, the possibilities of plastic construction. Airplane is powered by a Cirrus Minor 90-hp. engine and has an estimated top speed of 125 m.p.h. Construction, characteristics, performance. Flight, December 9, 1937, pages 580d–581, 7 illus. Aeroplane, December 8, 1937, pages 715–716, 3 illus.

ITALY

**The Four Winds.** Italy has improved one of her own records and broken another. First a Savoia S.79 took off from Guidonia and, at an average speed of 444.115 km./hr., completed 1000 and 2000 km. with a 2000-kg. load. A second record was established by another S.79 fitted with three Alfa-Romeo 126s, instead of Piaggios, over 1000 km. with 5000 kg. load at an average speed of 401.965 km./hr. Brief references. Flight, December 9, 1937, page 575.

**That Breda 88.** Averaging 554.35 km./hr. in his Breda 88 fighter bomber F. Niclot has broken his own speed record over 100 km. The Breda 88 was powered by two new 875/1000-hp. Piaggio XI R.C.40 14-cylinder radials in place of the French-designed Gnôme-Rhône K.14s of the previous version. The newer version is in production for the Italian Air Force and is said by pilots to be stable and maneuverable and as easy to take off and land as present standard types. Brief reference. Flight, December 16, 1937, page 607.

**Beltrame "Colibri" Canard Airplane.** A. Frachet. Unusual type of Italian airplane without ailerons or rudder and having a simplified system of piloting. Powered with an 18-hp. engine, also designed by Beltrame, the airplane has a maximum speed of 160 km./hr. and lands at 60 km./hr. Alighting gear consists of two wheels in tandem and protection for the wing tips. Les Ailes, November 18, 1937, page 9.

**Fiat. G.18V Bimotored Civil Airplane.** Low-wing 18-passenger monoplane (two Fiat A.80 R.C. engines each developing 1000 hp. at 4100 meters) has a maximum speed of 400 km./hr. at 4650 meters and carries a useful load of 3600 kg. Long description. L'Aerotecnica, August–September, 1937, pages 800–807, 6 illus.

**The Four Winds.** Record-breaking Cant Z.506 seaplane (Italian), fitted with three Pegasus-type engines, has climbed to 24,311 ft., carrying a useful load of 400 lb. Former record was held by the same machine. Brief reference. Flight, November 25, 1937, page 505.

**Stopani Climbs to 8951 Meters with 2000 Kg. Load in the Cant Z-506.** New altitude record with a 2000-kg. load recently made by Stopani in the Cant-Zappata Z-506B bomber seaplane (three Alfa Romeo 127 RC-50 680-hp. engines). The seaplane can carry a load of 4000 kg. at a maximum speed of 390 km./hr. Short note. Les Ailes, November 11, 1937, page 4.

JAPAN

**Foreign News.** Newest army reconnaissance plane being used by the Japanese Air Force in northern China is the two-place type 94 all-metal biplane having fabric-covered wings and stressed-skin fuselage. Power is supplied by a 550-hp. radial giving a maximum speed of 185 m.p.h. Ceiling is 26,250 ft. Very few details and reference to establishment of a Japanese-controlled aircraft factory in Mukdon early next year. Aero Digest, December, 1937, page 113.

U. S. A.

**The Four Winds.** Model flying boat weighing 1860 lb. and having a span of 43½ ft. and two propellers driven by belts from a single engine has been built by Martin and is providing useful aerodynamic and hydrodynamic data. Brief reference. Flight, December 16, 1937, page 601.

**The Russian Martin.** Martin 156 four-Cyclone powered flying boat of 63,000 lb. gross weight and accommodating 46 passengers by day. Short description of flying boat now making its initial flights. Flight, December 16, 1937, page 604b, 3 illus.

**Development of Curtiss P-36A Pursuit.** D. R. Berlin. Development of this pursuit airplane for the Air Corps is described in detail and performance, stability, maneuverability, controllability, and maintenance and manufacturing costs are considered. Long article. Aero Digest, December, 1937, pages 54, 56, 58, 7 illus.

**Martin Ocean Transport.** Model 156 long-range four-motored flying boat carrying more than 10,000 lb. of payload. Twin rudder tail improves control in flight, particularly with one engine stopped. Fuel is carried in the seawings. Changes in the wing are more aerodynamic than structural. An important feature of the specially designed flap is the antidrag shutter. Wing span is 157 ft., overall length 91 ft. 10 in., cruising speed 145 to 170 m.p.h., and range 3500 (route) miles. Level flight can be maintained at 10,000 ft. with only three engines operating at normal power. Long description of transport and comparison with China Clippers. Aviation, December, 1937, pages 36–37, 40, 82, 11 illus., 1 table. Short note on transport for Russia. U.S. Air Services, December, 1937, page 21, 1 illus.

**More About that Waco 3-Wheeler.** H. Perry. Advantages of nose-wheeling and details of construction and performance of the Model N-8 Waco biplane (Jacobs L-5 285-hp. engine, top speed 154 m.p.h.). Aviation, December, 1937, pages 34, 77, 3 illus., 1 table.

**Piper Aircraft Cub J-3 "Sport" Plane.** Powered with a 40-hp. Continental engine, the airplane has a top speed of 88 m.p.h. Description including some of the 50 changes in construction and appearance over the previous model. Aero Digest, December, 1937, page 48, 3 illus., 1 table. Description of "Sport" and "Trainer" models. Aviation, December, 1937, page 43, 3 illus., 1 table.

**Producing the Ryan S-C.** T. C. Ryan. Manufacturing methods developed in conjunction with design to simplify metal plane production problems through utilization of the drop hammer forming process. Material and supplies used and characteristics and performance of the airplanes are also given. Aviation, December, 1937, pages 32–33, 82, 10 illus., 1 table.

**Seversky Multi-Purpose "Convoy Fighter."** Two-place Convoy Fighter is adaptable, without structural changes, to the installation of engines ranging from 400 to 1200 hp. permitting the ship to be used for a multiplicity of purposes from basic training to light bombing. Different engine installations are designed as individual units, all of which are so arranged as to fit not only the four attachment points at the firewall of the fuselage, but also fuel and oil lines, wiring and controls. Long description of construction, armament, specifications and performances. Aero Digest, December, 1937, pages 78, 80, 6 illus., 1 table.

**Warner-Powered Ryan Monoplane.** Ryan Model SC-145W three-place metal cabin monoplane powered with a 145-hp. Warner Super-Scarab engine has a top speed of 150 m.p.h., cruising speed of 135 m.p.h. and cruising range of 500 miles. Long description. Aero Digest, December, 1937, page 74, 2 illus., 1 table.

## Air Transportation

**Scientifically to Sweden.** H. A. Taylor. Flying on the British Airways' run to Hamburg and Malmö, equipment of the Lockheed Electras used, use of power and altitude charts for long-range efficiency, blind-approach technique, simplified navigation, weather, and ice removal. Flight, December 23, 1937, pages 618–622, 5 illus.

**Kennedy Urges Loans up to 75% of Cost of Ocean Aircraft.** Flying boats will be able to render service comparable to that of the "Normandie" or "Queen Mary" at much lower cost. Loans for building of aircraft for the foreign trade up to 75 percent of the cost and a system putting transoceanic flying under supervision of the Maritime Commission are urged. Parts of report presented by J. P. Kennedy to Congress on November 17 are quoted and discussed. U.S. Air Services, December, 1937, pages 14–15.

Discussion of report quoting opinions of Loening. Aviation, December, 1937, pages 55, 64, 66, 1 illus.

**Operators Project Safety Program for Winter Operation.** T. P. Hay. Slowing down schedules, cancellation of flight, flight planning, adoption of de-icing equipment, and radio refinements. Means being taken by United, Eastern, Pennsylvania-Central, American, Northwest, Pan American, Braniff, and Boston and Maine airlines to insure safe operations during the winter. Aero Digest, December, 1937, pages 24–25, 102, 104, 3 illus.

## Airships

**Dr. Eckener Has a Hot Helium Idea.** To prevent wastage of helium it is planned to prewarm the gas cells of the LZ-130 airship before take-off, thus permitting full-capacity buoyancy without gas loss as the ship climbs to cruising altitudes. Water recovery apparatus will further eliminate valving to compensate for consumed fuel. Brief reference. Aviation, December, 1937, page 68.

**Events Abroad.** U.S.S.R. still retains a few airships in use. The reconstructed V-6 of 20,000 cu. cm. carries 21 passengers and is to be used on passenger service between Moscow and Sverdlovsk some 700 miles east of Moscow. Brief note. R.A.F. Quarterly, July, 1937, page 325.

## Balloons

**Balloon Barrages.** Air Commodore J. G. Hearson. There are to be no balloon aprons in the future. Tethering cables will be the only obstruction to the raiding bomber and will be made lethal in a way not revealed. Perimeter method sites balloons at 100-yard intervals at a radius of 10 miles from the center of London reaching a height of 2 miles and requiring 1100 balloons. The field siting method advocated by the author gives a greater chance of impact for a smaller number of cables, the design illustrated showing 600 balloons sited at equidistant intervals over the same area as covered by the perimeter method. The paper covers: both methods of siting balloons, their advantages and disadvantages; lethality of the cables; vulnerability of balloons; and the barrage in storms. A balloon barrage as part of the air defences of London is said to be almost an accomplished fact. Long abstract, Royal United Service Institution paper. Flight, December 16, 1937, pages 608–609, 2 illus.

Abstract and discussion. Aeroplane, December 22, 1937, pages 782–783, 1 illus.

## Propellers

**Curtiss Constant-Speed Propellor.** Design features which make this type of propeller especially suitable for high-speed military aircraft. Long description. Aero Digest, December, 1937, pages 60, 62, 3 illus.

## Aircraft Instruments and Navigation

**Simplifying the Blind Approach Problem.** Dial of the Short and Mason instrument panel has two hands, one indicating distance covered during the approach at any predetermined ground speed, and the other the airplane's height above the airport. Equipment also includes a small fluorescent screen in which cathode-ray indications are given of the directional position of the airplane in relation to the beam, two usual marker-beacon indicating glow lamps, and a third lamp set to glow by means of a landing stick or cord when the airplane reaches a predetermined minimum height. Description of D. N. Sharman's blind approach instrument panel. Flight, December 16, 1937, page 611, 1 illus.

**Finding Your Way in the Air.** Lt. Comdr. P. V. H. Weems. Celestial navigation theory, solution of the astronomical triangle, circles of equal altitude, plotting a position line on a chart, the fix, position lines by azimuth, and limits of accuracy. Aviation, December, 1937, pages 28–29, 73, 77, 5 illus.

## Airports and Airport Equipment

**Anemometer.** Stewart type B standard 4-cup anemometer said to be sensitive to wind as low as 3 m.p.h. and guaranteed to withstand a wind of 75 m.p.h. Brief note. Aviation, December, 1937, page 48.

**Dealing with Snow at Airports.** H. L. M. Knight. Snow removal methods in use at various airports, including the pusher or rotary plow, compaction, and air blowing methods. Compaction equipment designed by L. D. Hammond for use at Minneapolis Airport is described which consists of three light corrugated rollers for compaction (each equipped with surface scraper), a drag unit, and two-row hookup of five harrows. Aero Digest, December, 1937, pages 26–27, 7 illus.

**New Base for U.S. Army at Bolling Field.** Construction is described in detail. Aero Digest, December, 1937, pages 42, 96, 98, 2 illus.

## Ice Elimination Equipment

**Croydon Notes.** Recent troubles with ice formation on airplanes entering Croydon Airport indicate that pilots are unconverted to Kilfrost as a preventive and that ice actually formed over the paste. Suggestion is made that the right texture or composition of paste for dynamic, as differentiated from static, ice has not yet been discovered. Brief note. Aeroplane, December 15, 1937, page 769.

**Ice and De-Icing.** Brief editorial referring to the American Goodrich pneumatic inflatable leading-edge system and to J. Halbert's Kilfrost paste tried out by Imperial Airways. Comment is made that "Time will show whether Kilfrost is a real solution of ice menace or just a very timely Political Paste." Reference is made to a new idea working in a way something like the Lockspeiser method.

**Professional Notes.** No. 22 of the British Meteorological Office on the subject of "Ice Accretion on Aircraft" is reviewed. Aeroplane, December 1, 1937, page 661.

**Air Ministry Notice.** Deicing devices required for British aircraft. Brief notice. Aircraft Engineering, November, 1937, page 303.

**Slinger Feeder.** Siebenthaler deicer-liquid metering pump. Brief reference. Aviation, December, 1937, page 47, 1 illus.

## Miscellaneous Equipment

**Aircraft Spotting Device.** Instrument is a very delicate heat detector which, through use of infrared rays, can trace the fastest fighting plane flying without lights and engine shut down. Short note on experiments taking place at Fort Monmouth. R.A.F. Quarterly, October, 1937, pages 477–478

**Ground Apparatus Supplements Training in Instrument Flying.** H. S. Pack, Jr. Link Trainer is described in detail, courses offered by American and United Air Lines are outlined, and a general problem work in orientation discussed. Aero Digest, December, 1937, pages 38–39, 96, 5 illus.

**Self Locking Screw.** Shakeproof Lock-tite vibration-resisting screw cuts its own threads in metals and plastics of practically any thickness. Brief note. Aviation, December, 1937, page 48.

**Aerodrome Bumps Indoors.** Test rig developed by Automotive Products Company to test Lockheed "Airdaulic" undercarriage struts. Wheel can be loaded to any weight and any required ground speed reproduced, cams on rollers representing ground-surface bumps. Photo only. Flight, December 9, 1937, page 592, 1 illus.

**A Fireproof Flying Suit.** New Bell asbestos outfit consists of overall, boots, gloves, and helmet. Material can be waterproofed and lined with either a blanket material or ordinary twill. Weight of present model is 13 lb. 9 oz. Short description. Aeroplane, December 22, 1937, page 798. Flight, December 16, 1937, page 613.

## Engine Design and Research

**The Advantages and Possibilities of the Liquid-Cooled Aero Motors from the Rolls-Royce Point of View.** Progress of the 12-cylinder 60° vee type over the last ten years; merits of liquid cooling; operation in cold climates; cooling system developments on engine and aircraft; high-temperature cooling and reduction of cooling drag of aircraft; future engine forms; and means available for obtaining increase in power including higher mean effective pressures, increased piston speeds, increased capacity and reduction of powerplant drag. Return to use of water cooling without effective loss in performance is proposed. Increase of the maximum-performance height of the Merlin II due to the use of the Rolls-Royce type of venturi forward-facing air intake is referred to. Aeroplane, December 15, 1937, pages 733–737, 6 illus.

**Air-Cooled Aero-Motors.** A. H. R. Fedden. "The extremely rapid and important development of the high-performance medium bomber has definitely been made possible by the radial aircooled engine and it is now well known that Britain has a lead over other countries in this respect." Performance at heights of 15,000 ft. and upwards now within the range of very much heavier bombers, advantages of the sleeve valve, and future trends in regard to powers developed and layouts of powerplants. The author predicts inline aircooled engines of 4 to 6 liters, single-row radials of 15 to 30 liters capacity for four-engined moderate-sized civil aircraft, double-bank radials of 35 to 45-liter capacity for heavier land planes and flying boats, and compact double-bank radials of 25 to 50-liter capacity for military aircraft. Aeroplane, December 15, 1937, pages 728–732, 7 illus.

**Endurance and Fuel Consumption.** H. Constant. Suggestion for reduction of engine weight by lowering of compression ratios. Conditions under which total power plant and fuel specific weight become a minimum are considered. Variation with compression ratio of the total specific weight of power plant and fuel has been calculated, and variation in the total specific consumption with compression ratio is plotted. Aircraft Engineering, December, 1937, page 329, 1 illus., 1 table.

**Determination of Fuel Jet Impact in Diesel Engines and Its Distribution.** J. Geiger. Jet was allowed to impinge on a small plate carried on a spindle passing through the cylinder head. Length of the plate arm can be varied and boundaries of the fuel jet outlined. Experiments were mostly carried out with the engine motored and the use of nitrogen instead of air. Power runs indicated that the vane mechanism withstood the combustion process remarkably. Effect of turbulence on breaking up of the jet is shown in indicator diagrams. V.D.I., August 7, 1937, pages 948–949, 3 illus.

**Fundamental Problems Associated with Flying in the Stratosphere.** J. P. Eames. Formulas for resistance offered to motion of an airplane and magnitude of atmospheric density relative to any desired altitude, and the problems of supercharging. Drawings of the Farman type two-stage impeller and compressor of the 500-hp. Renault engine are included. Aero Digest, December, 1937, pages 28, 94, 2 illus.

**The Mechanics of Flame and Air Jets.** R. F. Davis. To obtain a complete picture of a flame jet in which the combustible is projected at high velocity from a nozzle, the progress of combustion must be correlated with the dispersive characteristics of the jet. Turbulent mixing region formed by a jet, overfire air jets, flame jets, ignition and rate of propagation in flame jets. Continued. Long abstract, Institution Mechanical Engineers paper. Engineering, November 26, 1937, pages 608–610, 14 illus. 12 equations.

**Radiation of the Combustion Chamber of High-Speed Diesel and Otto Engines.** L. Bisang. Investigation with an infrared sensitive photo cell. The method described was developed for measurement of temperature distribution and enables an inertia-free recording of the temperature radiations which are responsible for the heat transmission to the cylinder walls, valves, and pistons. Results of tests for Diesel and Otto-cycle engines are discussed and a method for experimental calibration in temperature values is given. V.D.I., July 3, 1937, pages 805–809, 10 illus.

**Radio Shielding on Air Transports.** H. E. Gray. Paper previously abstracted from preprint (see TECHNICAL DATA DIGEST, May 15). S.A.E. Journal (Trans.), November, 1937, pages 527–530, 544, 4 illus., 2 tables.

**A Supercharger of High Efficiency.** M. Victor. Due to the work of Szydlowski and Planiol it is now possible to equip engines with superchargers having an adiabatic efficiency of 80 per cent which allows the engine to operate at full power at an increase of altitude of more than 2000 meters. These very important results were obtained by an aerodynamic study of all the elements of the centrifugal compressor. Characteristic curves of the L.S. 1000 supercharger and the L.S.-40 supercharger for a 100 to 120-hp. engine and its rotor are illustrated. Long discussion of advantages obtained with the use of this supercharger but little about the design. Les Ailes, November 11, 1937, page 8, 4 illus.

**Diesel Engine Practice.** A. E. Thieman. Changes in European Diesel engine practice. French Berliet has adopted the Ricardo Whirlpool combustion chamber, Compagnie Lilloise de Moteurs automotive and railcar models of the Junkers aircraft engine, John Fowler and Company is using a new

type of turbulence chamber due to F. Saunders, and Renault has adopted the Ricardo Comet-type head. A.T.Z., October 25, 1937.

Brief abstract. Automotive Industries, December 4, 1937, page 800.

## Engine and Fuel Testing

**Aivaz Universal Test Stand.** Two variable-pitch brake propellers permit the measurement of engines developing from 50 to 1200 hp. with an approximation of 1 per cent. The bed can be pivoted for testing the engine at various inclinations. Rev. de l'Armée de l'Air, August, 1937, pages 945–946, 3 illus.

**Electrodynamic Performance Balances.** E. Loetterle. Electrical connections by means of which engine performance can be directly indicated or recorded in horsepower. For the measurement of single values, the torque, friction and ventilating moments and r.p.m. are considered. Mathematical and electrical determination of performance is discussed and the bearings, cooling, and insulation of the machine are described. Types of current balances are reviewed and application of the machine as a single-cylinder test stand, as aircraft-engine test stand, and for special purposes are discussed. The DVL single-cylinder test stand with the electrodynamic performance balance is illustrated. V.D.I., October 9, 1937, pages 1187–1193, 23 illus.

**The S.N.C.M. Has Opened an Unusual Station on Mont Blanc for Altitude Tests.** M. Victor. Visit to the high-altitude test station of the Société Nationale de Construction de Moteurs where engines will be tested under natural conditions of high altitude. Les Ailes, November 18, 1937, pages 7–8, 11 illus.

## Engine Maintenance

**Extending Engine Overhaul Periods.** Report made by T. H. Kinkade after inspection of three Wright 750-hp. engines completing 500 hours of scheduled air transport operations is expected to result in Government permission to extend Eastern Air Lines major overhaul periods from 525 to 600 hours. Short note. Aero Digest, December, 1937, page 88.

**Plug Conditioner.** Siebenthaler spark plug tester, a point setter, a point cleaner, and a special assembling tool designed specifically for servicing radio-shielded aircraft-engine spark plugs. Brief reference. Aviation, December, 1937, page 48, 1 illus.

## Engine Manufacture

**Navy-Built Airplane Engines.** R. R. Wiese. New plant in Philadelphia gives the Government 25 engines per week, if needed, a shop for experimental engine construction and another yardstick for measurement of costs. Brief description. American Machinist, December 1, 1937, pages 1134–1137, 5 illus.

## Engines

**Continental Develops 50 Hp. Engine for Small Planes.** A-50 four-cylinder horizontally-opposed aircraft engine developing 50 hp. at 1900 r.p.m. Long description. Automotive Industries, December 25, 1937, pages 905–908, 914, 4 illus., 1 table.

**Herrmann Barrel-Type Engine.** Barrel-type of internal-combustion engine said to be especially suitable for aircraft. Crankshaft is replaced by a cam plate which imparts a simple harmonic motion to the reciprocating parts. A 12-cylinder engine developing 140–150 hp. at 1900 r.p.m. is illustrated and described in detail. Automotive Industries, December 18, 1937 pages 902–903, 914, 6 illus.

**Inverted Vee Aero Engine.** Junkers Jumo 12-cylinder inverted-vee water-cooled aircraft engine of small frontal area, develops 680 hp. at 2700 r.p.m. and is designed to use 87-octane gasoline. Weight is 975 lb. Brief description. Automotive Industries, December 25, 1937, page 896.

Few details of Junkers Jumo 210. Les Ailes, August 19, 1937, page 9, 1 illus.

### Parts and Accessories

**Air Ministry Official Notices.** Instructions to ground engineers and private owners on essential modifications include: jointings for use in fuel, oil or water systems of civil aircraft and purposes for which Petro-Flex, Superflexit and Avioflexus tubing may be used as well as precautions to be taken in connection with fitting flexible tubing. Aircraft Engineering, December, 1937, pages 332–333, 3 tables.

**Approval Tests of the Hispano Suiza 14 AB.** Successful tests of the 14 AB two-row radial engine (rated at 710 hp.) which has been purchased by Czechoslovakia. Results with the engine mounted on the Potez 63 are given. Les Ailes, November 11, 1937, page 9.

**Argus Aircraft Engine.** Model AS-10-C Series 3 German 8-cylinder inverted-vee developing 240 hp. at 2000 r.p.m. (for 5 minutes) and rated at 200 hp. continuous output at 1880 r.p.m. at sea level. Description and drawings, one full page. Automotive Industries, December 11, 1937, pages 849–850, 2 illus.

**British Aero-Motors of 1937.** Characteristics and performance of 49 aircraft engines. The Alvis Alcides is rated at 1750 hp. at 2250 r.p.m. at 5500 ft. for maximum level flight and the Alcides Major at 1640 hp. at 14,500 ft. A second article gives photographs of 28 British aircraft engines. Aeroplane, November 24, 1937 ,pages 620 and 641–644, 28 illus., 1 table.

Table of performance figures for the Armstrong-Siddeley, Bristol, De-Havilland, Napier and Rolls Royce engines. Flight, November 25, 1937, page 514*l*, 1 table.

**Lycoming R-530-D Engine.** Two new 7-cylinder radial aircooled engines. Model R-530-D1 engine has a normal sea-level rating of 200 hp. at 2100 r.p.m., and take-off rating with controllable-pitch propeller of 220 hp. at 2300 r.p.m. Model R-530-D2 is rated at 190 hp. at 2100 r.p.m. and 210 hp. at 2300 r.p.m. for take-off. Long description. Aero Digest, December, 1937, page 76, 2 illus., 1 table.

**A Push-or-Pull "Four."** New Czechoslovakian Praga D and DR horizontally-opposed aircooled 4-cylinder engines, developing 79/80 hp. maximum at 2610 r.p.m., and 90 hp. at 3000 r.p.m., respectively. Short description. Flight, November 18, 1937, page 486, 2 illus., 1 table.

**A Splendid Liquid-Cooled Engine.** Professor Klemin's description and comments on the Allison V-1710 aircraft engine. Scientific Am., November, 1937, pages 308–309, 2 illus.

**Technical Notes.** The large Hispano-Suiza wind tunnel, recently completed, uses 4000 hp. and 350 km./hr. speed in a jet 5 meters in diameter. Full-scale fuselages and new systems of radiators will be tested there. Underground a test chamber 200 meters long has been built for tests of the 20-mm. cannon Hispano Suiza is studying means of increasing the power of the 12Y by means of a cylinder head with four valves, instead of two, for increasing the rate of filling the cylinders. They are also studying a 24-cylinder engine composed of two 12Ys joined along the line of the shaft, the normal one above and the other inverted below. There will be two crankshafts, one for the 12 cylinders to the right and the other for those to the left, each acting with a unique reduction gear according to the principle of the Bréguet-Bugatti engine of 1920. Brief references. Les Ailes, November 18, 1937, page 9.

**Romec Engine-Driven Fuel Pump.** Type G-2 Model 15-B4D-2X fuel pump described has a cushioned lubricated pressure-compensated pump shaft, fuel leakage seal to meet requirements of new types of pressure carburetor and fuel-injection equipment necessitated by demand for high altitude operation. Aero Digest, December, 1937, page 89, 2 illus.

**System of Octane Control.** Anilol antiknock fluid mixture installation produced by Fuel Development Corporation. System controls octane values whereby the octane rating is automatically increased with throttle opening. It is also an effective carburetor ice-removing agent and is of use to bimotored airplanes during enforced single-engine operation. Aero Digest, December, 1937, page 88, 1 illus.

## Metals

**Corrosion of Aluminium.** H. Lichtenberg. Corrosion protection of aluminum by means of additions to the corroding medium, including inhibitors preventing corrosion by acids and by alkaline solutions. Very brief abstract from Aluminium, 1937, 19, 504. Metal Industry, December 10, 1937, page 574.

**Cyaniding—Nitriding.** L. Guillet. These two processes and a practical method for determining which process had been used in any particular case are discussed. Brief abstract of article criticizing a previous one entitled "Modern Aircraft Engines" in which these two processes of hardening cylinder bores were confused. From Le Génie Civil, November 20. Automotive Industries, December 18, 1937, page 864.

**A Particular Application of Autogenous Welding: Use of Specially Superposed Metal for Reinforcing Aircraft Parts.** F. Bonifacio. Results of tests of reinforcement with specially superposed metals, among them chrome steel, and precautions to be adopted in applying the method to aircraft parts. Microstructure of the metals illustrated. L'Aerotecnica, August-September, 1937, pages 762–764, 2 tables, 7 illus. on supl. plates.

**Pre-Forming Metal Sheets in U.S.A.** A. Klemin. Cairns method of rolling wide sheets of any desired length to compound curvature is described in detail and reference is made to results of a fuselage test at the Naval Aircraft factory. Other modern American preforming operations described cover stretching and hammering, use of the drop hammer, and use of large hydraulic presses. Aircraft Engineering, December, 1937, pages 325–327, 5 illus.

## Testing of Materials

**Polarization Optical Layer Method for Measurement of Surface Stresses in Stressed Structural Parts Without the Use of Models.** G. Oppel. On the surface of the part, the stresses and changes of form of which are to be measured, an adhering penetrating film is applied. In a nonstressed condition this film shows an optical noncrystalline condition but, in case of induced deformations, will assume an optical crystalline condition. Such layers can be produced from cellulose or natural and synthetic resin. Before applying the film, the surface is polished or silvered so that light can be refracted. In case of metals treatment with fine emery cloth is sufficient. V.D.I., July 3, 1937, pages 803–804, 4 illus., 2 equations.

**Structural Tests of Synthetic Resin Pressed Materials.** Method for microscopic investigation of these pressed materials. Production of suitable test pieces, means of rendering the microstructure visible by fine filling particles, observation of photographs, applications of method and chemical investigation. V.D.I., August 7, 1937, pages 935–938, 10 illus.

## Aircraft Radio

**Aero Radio Digest.** Air Radio Model AR-30-W radio-telephone transmitter. Radio Receptor range goniometer unit. War television tests being conducted at the Hendon Royal Air Force airport. Air Track instrument landing system. Aero Digest, December, 1937, page 90, 4 illus.

**Bendix Announces two New Receivers for Communication and Beacon Use.** RA-4 beacon receiver is an 8-tube superhet using one r-f stage and two i-f (157 kc.) stages covering the range from 195 to 415 kc. continuously. RA-2 communications receiver is designed for voice communication in the band from 2600 to 7000 kc., in which any 8 preselected frequencies may be chosen. Long description. Aviation, December, 1937, page 44, 2 illus.

**Helping the Pilot.** Information which the pilot of a two-seater or multi-seater bomber should receive during flight, and a suggested system for England for guiding the pilot by radio and for broadcasting weather reports. Article is written from the point of view of the pilot rather than the radio engineer. R.A.F. Quarterly, July, 1937, pages 265–269.

**Radio Developments of the Bureau of Air Commerce.** H. W. Roberts. Bureau's radio organization, and work of the Radio Development Section, including: ultra-high-frequency radio range beacon and its experimental installation at Indianapolis, tests on a 125-mc. airport traffic control radio-telephone transmitter, and other ultra-high-frequency transmission work. Aero Digest, December, 1937, pages 34, 36–37, 94, 4 illus.

**War Television.** Radio television camera equipment, understood to be the product of Marconi Wireless Telegraph Company, is being tested at the Royal Air Force airport at Hendon, according to reports. The camera, carried in an airplane over enemy lines, will transmit an image of enemy positions, artillery placements, and troop concentration. Image is received at staff headquarters where it is projected on a screen providing up-to-the-second information on enemy movements. Brief note. Aero Digest, December, 1937, page 90.

## Meteorology

**College Notes—Massachusetts Institute of Technology.** Photographic method of nocturnal wind soundings devised by A. F. Spilhaus. Method makes use of a "whole sky camera" having a 180-degree lens, a pilot balloon, and magnesium flares attached at intervals to a length of ordinary blasting fuse. The camera lens on the earth is pointed upward and as the sounding balloon ascends, flashes of flares ignited at known intervals are recorded on plate. Test plates have been made for recording magnesium flashes at distances of as much as 7 miles and at heights of over 13,000 ft. Brief note. Journal Engineering Education, November, 1937, page 245.

**Moltchanov on the Results of Radiometeorograph Soundings During 1930-36 in the U.S.S.R. and the Arctic.** Results indicate how largely the polar regions are dominated by radiation processes which tend toward an isothermal vertical distribution of temperature. This prevalence of stable conditions in the Arctic troposphere should tend to make flying conditions there more favorable than to the South. Abstract from Bulletin of the Arctic Institute, Leningrad, No. 6, 1936. American Meteorological Soc., Bulletin, October, 1937, pages 322–325, 5 tables.

**The Relationship Between Airline Dispatching and Meteorology, with Reference to the Practice of the United Air Lines.** O. T. Larson. Dispatching practices of this airline, points covered in the trip forecast and flight plan, and recommendations for improvement and refinement of existing facilities and practices. American Meteorological Soc., Bulletin, October, 1937, pages 331–335.

**Speed of Winds at 5000 to 10,000 Meters Altitude over the United States and the North Atlantic.** Results given by L. A. Stevens in the Bulletin of Air Commerce are quoted and compared with those obtained in aerological soundings carried out by German ships over the North Atlantic. Rev. de l'Armée de l'Air, August, 1937, pages 913–920, 1 illus., 3 tables.

**Psychology and the Royal Air Force.** F. C. Bartlett. More important points of contact between psychology as it is today and any military air force. First issue—Problems in selection of air force candidates; question of accidents; special conditions; and general social problem. Second issue—Possible methods for studying interests (interest inventory, group survey and other methods), temperamental qualities and behavior (rating scale, experiment, and other approaches, personal interview, and character). Author is professor of experimental psychology, University of Cambridge. To be continued. R.A.F. Quarterly, July and October, 1937, pages 270–276 and 375–487.

**Study of Physiology and Psychology of Italian Pilots.** Results of experiments conducted on a Caproni CaIII equipped as a flying laboratory, were reported at the Congress of Aeronautical Medicine held in Milan, October 9 to 10. Brief reference only. Les Ailes, November 11, 1937, page 6.

## Aeronautical Industry and Production

**Aircraft Output up 25%.** During the first 9 months of 1937, aircraft manufacturers produced 2757 airplanes (484 for delivery to military services), 22 gliders and 9 lighter-than-aircraft. A few statistics. Automotive Industries, December 11, 1937, page 829.

**British Aircraft Constructors.** Lists of aircraft constructors, aircraft-engine builders, and suppliers to the aircraft industry of materials, component aircraft and engine parts, accessories, and airport and workshop equipment. Aeroplane, November 24, 1937, pages 645–648.

**Favorable Business Trends in the Aviation Industry.** J. Foster, Jr. Prospects for the industry during the new year, with reference to backlog of orders of the various companies and types of aircraft they are producing. Aero Digest, December, 1937, pages 29, 98, 100, 2 illus.

**Getting Ready for Bigger Airplanes.** New assembly building for Glenn L. Martin Company has clear floor area the size of a large city block to accommodate construction of the super Clipper ships of the future. Ground dimensions 308 × 453 ft., overall height 74 ft., clear ceiling height 40 ft. under the cranes. Long description. Engineering News Record, December 9, 1937, pages 936–946, 8 illus.

**More Space, More Light, More Efficiency.** United Aircraft addition for the Hamilton Standard Propeller Division shows a substantial advance in design over the original factory which was ultra-modern in 1930. In the new addition bays are increased to 64 × 64 ft. Long description. Engineering News Record, December 9, 1937, pages 933–936, 5 illus.

**Moving to the Country.** Bendix Aviation Corporation new 360,000-sq. ft. plant on the New Jersey meadows is distinguished by welded cantilever roof trusses. Long description. Engineering News Record, December 9, 1937, pages 953–955, 3 illus.

**On the British Aircraft Industry.** C. G. Grey. Question of what is waste and what is necessity in regard to rearmament, benefit of Royal Air Force expansion, development of British aircraft industry, metal versus timber for aircraft, and British quality. Aeroplane, November 24, 1937, pages 615–617.

**The Shadow Factories.** Aircraft-engine units produced, interesting production methods, and machine tools used at the Roots, Daimler, Standard, Rover, and Austin plants. A battery of Asquit profile machines was built specially to British Air Ministry requirements for milling sector-shaped pockets between radial blades of the impeller. Automobile Engineer, November, 1937, pages 444–446, 5 illus.

**Air Ministry Official Notices.** Lists of approved firms producing aircraft, propellers, aircraft components, radio, tire, instruments, and equipment as well as those especially approved in connection with experimental or test flights of aircraft. Aircraft Engineering, December, 1937, pages 332–333.

**Suppliers to the Aircraft Industry (British).** British suppliers of raw materials, component parts and accessories for aircraft and aircraft engines, tools and equipment for aircraft construction, supplies and equipment for aircraft operation, and airport and factory construction. Names, addresses, and products. Hobson electrical ice-warming unit which fits the carburetor, Harley landing light, Smith's flap indicator, and production equipment illustrated. Aeroplane, December 15, 1937, pages 751–768, 9 illus.

## Air Forces

**Activities of the Air Force in the German 1937 Maneuvers.** G. W. Feuchter. Part played by the Air Force in operations September 20 to 26. This is followed by articles describing Italian, British, and French maneuvers during August. Luftwehr, October–November, 1937, pages 392–397, 397–398, and 399–402, 16 illus.

**Foreign Service News.** Canadian Car and Foundry Company, which holds the Grumman license, has sold 40 fighters to Turkey and three to Nicaragua. Canada is buying 20 more flying boats on next year's defense budget. Five Supermarine Stranraers are now under construction at the Vickers plant in Montreal. Brief references. Flight, November 25, 1937 page 215.

**France Has Produced Two Modern Airplanes Used by Japan and Russia.** G. Houard. Bréguet Vultur, first of its class to exceed the 400 km./hr., is built in Japan under license and is used in Japanese military operations in China. Caudron Renault sold the same rights to Russia for its pursuit airplane. Brief note. Les Ailes, November 18, 1937, page 3.

**League Defence Council Meeting, 1945.** Flight of imagination purporting to record verbatim a meeting of such a council in 1945, to consider the possibility of developing an International Air Force. R.A.F. Quarterly, October, 1937, pages 406–412.

### France

**The Splendid Start of the Air Maneuvers Overseas.** Without an accident and with perfect regularity, more than 70 airplanes of the Armée de l'Air crossed the Mediterranean from Istres to Tunis. Details of the flights planned and airplanes participating in the French African maneuvers. Les Ailes, November 18, 1937, page 11, 1 illus.

**The Four Winds.** Ninety-eight aircraft took part in the French Air Force flight from the home country and Africa to Indo China. Maneuvers demonstrated that France was in a position to send from Europe to Africa, in a few hours, squadrons whose bombing capacity was immense. Brief reference. Flight, December 23, 1937, page 623.

**French Army Co-operation.** Creation of an air arm for the artillery with officers of the army as observers is under consideration. Editorial comment comparing this method with the R.A.F. system of using a pilot-observer and a gunner. Weak points in the latter system are pointed out. Flight December 16, 1937, page 595.

**A Night on Board a Bréguet-"Bizerte" Flying over the Ocean.** Commandant A. Langeron. A flight at night in bad weather during the recent French naval air maneuvers. Object of the exercises was to search for and attack two battleships on the Atlantic. Second issue describes the return flight after the maneuvers. Les Ailes, December 9 and 16, 1937, pages 11–12 and 11, 1 illus.

**Reorganization of the Technical Corps.** Modifications made to the Services Techniques du Ministère de l'Air. The S.T.Aè. in charge of prototypes and the S.F.A. organized for control of airplane production have been combined in the new Service Technique et du Contrôle. A Service de la Production has been organized as an Air Ministry agent for control of the nationalized industries. Duties of these two new organizations outlined. Les Ailes, December 9, 1937 page 8.

### Germany

**Events Abroad.** New Focke-Wulf 159 single-seater fighter; flight of a Junkers 86 to the Near East; use of substitute fuels in Germany (for buses, trucks, tractors); formation of the National Socialist Flying Corps (decree), aviation for the masses; and air-raid precautions. Brief notes. R.A.F Quarterly, October, 1937 pages 467–474.

### Great Britain

**Dive Bombing.** Dive bombing is not now very practical in the R.A.F. because modern airplanes reach such high speeds in a dive that it would be very difficult to pull them out if they did not break in the air. Remark of Air Chief Marshall Sir Hugh Dowding before the Royal United Service Institution. Editorial comment discussing the need for an air brake such as a flap or reversible-pitch propeller on dive bombers. Flight, December 16, 1937, pages 593–594.

**The Metropolitan Air Force.** There is a serious shortage of flight commanders in these squadrons. Two regular and five Auxiliary squadrons are 25 percent or more below strength in aircraft of the service type allotted to them and one regular and six Auxiliary squadrons are 25 percent below strength in pilots. There are 47 squadrons without a flight lieutenant and 33 without a flying officer, and of these 80 there are 15 without either. Brief note. Aeroplane, December 15, 1937, page 724.

**Bombers and Fighters.** There are at present in the Metropolitan Air Force 123 squadrons, of which 70 are bombers and 30 fighters. Of the 26 squadrons overseas, 15 are bombers. There are no fighters overseas. Brief note. Aeroplane, November 24, 1937, page 612.

**L.M.S. Air Raid Precautions Mobile Unit.** Unit of the railway company for training nearly 23,000 of its staff in approved methods of dealing with consequences of an air raid, including effects of poison gas and incendiary bombs. Editorial. Engineer, November 26, 1937, page 585.

**Mr. Perkin's Polemic.** House of Commons debate on charges of inefficiency against the British Air Ministry and conduct of British civil aviation in general. A departmental inquiry will be held by a Committee of Inquiry to investigate the charges. Editorial comment also given. Aeroplane, November 24, 1937, pages 649–652, 607–610.

Debate, and editorial comment. Flight, November 25, 1937, pages 527 499–500.

**A Regimental System for the Royal Air Force.** Flight Lt. F. J. St. G. Braithwaite. Criticism of frequent transfers of all ranks from squadron to squadron, and suggestion that each regiment consist of twelve squadrons, some of which would be devoted to specialized classes of duty and remainder to bombing or fighting. Recommendations for an engineering and armament regiment entrusted with all test, experimental and development flying are included. R.A.F. Quarterly, October, 1937, pages 368–374.

**To Australia.** No. 204 (General Reconnaissance) Squadron in five Saro London flying boats have started on a 25,565-mile cruise. Itinerary outlined. Flight, December 9, 1937, page 587.

### Italy

**"Attack" in Italy.** "The Italians, like the Americans, maintain that one of the most useful purposes for which the aeroplane may be employed is 'attack,' in other words assault or ground strafing . . . . In the development of special machines, emphasis has been laid on performance and control at low altitudes." Reference is made to armament of the A.P.1 and the Breda 65 (1000-hp. Fiat A.80 R.C.40 engine, 263 m.p.h., range nearly 750 miles). Both are normally two-seaters but may be employed as single seaters. Photograph illustrates staggered arrangement of the four fixed guns mounted in the wing. Brief. Flight, December 9, 1937, page 586, 2 illus.

Italian 1937–1938 estimates for Army, Navy, and Air Force; expansion of the Independent Air Force; organization of air forces in Libya; and other short notes. R.A.F. Quarterly, July, 1937, pages 319–321.

Creation of a supreme command of armed forces in Italian North Africa; air strategy (reference to interceptors capable of climbing to 24,000 ft. in 8 min. and fighters capable of over 310 m.p.h.); Air Estimates for 1937–38. Very brief notes. R.A.F. Quarterly, October, 1937, pages 474–475.

**The Four Winds.** Flying at about 20,000 ft. a squadron of Italian Fiat fighters recently crossed the Andes from Chile to Argentina in 40 minutes. Brief reference. Flight, November 25, 1937, page 505.

### Japan

Interdepartmental conference on aviation; government control of aircraft industry; and production of synthetic aviation fuel. Very brief notes. R.A.F. Quarterly, October, 1937, pages 474–476.

**On the War Star in the East.** C. G. Grey. "The Japanese can learn anything but can understand little." Opinions of British flying and technical instructors on a mission to Japan shortly after the world war are quoted with Mr. Grey's comments on the psychology of the Japanese people. Aeroplane, December 22, 1937, pages 775–776.

NETHERLANDS EAST INDIES

Thirty-nine Martin bombers (range 1100 miles with a 2000-lb. bomb load), and Fokker T.5 twin-engined bombers (maximum speed 236 m.p.h., bomb load 2200 lb., and range 1350 miles) have been ordered. Brief reference. R.A.F. Quarterly, October, 1937, page 476.

RUMANIA

**The Four Winds.** Rumania has ordered 30 Italian Nardi F.N.305 trainers, 24 Savoia Marchetti S.79 bombers, and 6 Savoia Marchetti S.83 transports. S.83s and bombers are triple-engined machines capable of about 260 m.p.h. Brief reference. Flight, November 25, 1937, page 505.

SWEDEN

Grants for air-raid protection; new antiaircraft gun (40-mm. gun effective at range of 3000 meters and firing 120 rounds per minute); and supply of British aircraft. Very brief notes. R.A.F. Quarterly, October, 1937, pages 476–477

U. S. A.

**Admiral Cook Reports.** Recommendations include: development of more satisfactory types of nonrigid airships and their more extended utilization in connection with fleet activities and for coastal missions according to a definite program. Early determination of the Navy's future rigid airship policy is requested. Parts quoted from the annual report to Secretary Swanson, including future developments. U.S. Air Services, December, 1937, page 30.

**Air Corps Boosts Contracts to 1200.** Air Corps "has more aircraft on order than on hand; approaches 10-year goal." Short review of orders. Aviation, December, 1937, page 56.

**Wartime Air Force Asked by Secretary Woodring.** Brief review of the Secretary's annual report to President Roosevelt, and quotations from a War Department statement regarding the Y1A-18 twin-engined attack airplane built by Curtiss. U.S. Air Services, December, 1937, page 22, 1 illus.

U. S. S. R.

**Repercussions of "Trotskyism" on Soviet Aviation.** Effects of the Soviet political events on military and civil aviation in the U. S. S. R. Les Ailes, August 12, 1937, page 5.

**Principles of Soviet Russia in Regard to Air Warfare.** Development of bombers in U. S. S. R. since 1932, and duties of the light bomber in warfare. A new four-motored heavy bomber is illustrated. Luftwehr, October–November, 1937, pages 407–413, 1 illus.

## Air Warfare

**Views on Air Defence.** By the Authors of Air Strategy. Ground observation, air observation and patrol, and combined action of destroyers and light single-seater fighters. Under the first heading the authors refer to the use of infrared rays in the future war and discuss antiaircraft stations and special silence zones quoting Listovsky on antiaircraft defence of Tokio. Concluded.

Answers to criticism of "Air Strategy" made in the July issue. Three air strategies, hitting power and speed, speed mania and bomb raids, battle lines and "mobile volumes," fighter-bomber, obsolete fighters, and air war and aerial "scrapping." R.A.F. Quarterly, July and October, 1937, pages 254–264 and 450–462, 1 table.

**Air Strategy.** Analysis and some criticism of General Golovine's book on this subject, covering the following points: air strategy and technical progress, hitting power or speed, merit in defense, intensity of gas attack, moral effect of air attack, fighter-bomber, role of the parachute squads, air aim of Great Britain, problems of British strategy, destroyers and bombers, danger in specialization, and scouts and light single-seater fighters. R.A.F. Quarterly, July, 1937, pages 245–253.

**Aircraft Ground Strafing Against Infantry.** Flight Captain de Caters. Advantages of the low attack, performances and light armor required for such aircraft, and objects of the squadron groups. From Bulletin Belge des Sciences Militaries, June. Luftwehr, October–November, 1937, pages 432–434.

**Command of Flight Formations.** Lt. Col. Césari. Reasons why the leader of flight formations should be capable of piloting an airplane, and suggestions for improving the bravery of officers of the flight formations. Rev. de l'Armée de l'Air, August, 1937, pages 889–902.

**Effect of the Air Force on Infantry and Infantry Defense.** Lt. Col. M. Spoerri. Absolute air control and performance and armament requirements are discussed for the two types of airplanes operating against the infantry, namely the single-seater pursuit (speed 350/500 km./hr., duration 2 to 3 hours) and the two-seater fighter (speed 300/400 km./hr., duration 3 to 5 hours). Types of bombs used against ground troops described include splinter bombs, flying-mice bombs (spezzoni), gas bomb, spraying of liquid from the airplane (in which notable technical practice has been obtained in the United States in combatting pests), and incendiary bombs. Duties of the pilot, cooperation with the infantry, defense of ground troops, and passive aerial defense of troops also discussed. Luftwehr, October–November, 1937, pages 413–419, 1 illus.

**Reconnaissance Against Enemy Air Forces.** Major Iljuchin. Means of obtaining valuable information in regard to location, aircraft on the ground and in the air, and aerial defence forces on the ground. From "Wjestnik wosduschnowo flota," February. Luftwehr, October–November, 1937, pages 428–432.

**Postponing Portugal.** Discussion of a mutal defence agreement between Portugal and Great Britain has been postponed at Portugal's request. Portugal's position in a war between Great Britain and the Fascist powers in the Mediterranean is considered in a long editorial. Aeroplane, November 10, 1937, pages 551–553.

## Miscellaneous

**Degreaser.** Curran Gunk degreasing compound for use in cleaning airplane parts and approved for use with aluminum. Compound is a water-in-oil type of solvent emulsion and work is simply immersed in a cold bath. Short note. Aviation, December, 1937, pages 47–48.

**How We Made the First Flight.** Orville Wright. Account of the first successful power-driven flight which appeared in the December, 1913, issue of the American periodical "Flying." U.S. Air Services, December, 1937, pages 10–13, 28, 30, 6 illus.

**Winter Flying in Canada.** Flight Lt. W. D. Van Vliet. Problems from the viewpoint of a mobile detachment working in the open. Atmospheric temperature; engine starting, lubrication, carburetion, and maintenance; aircraft alighting gear; structural problems and maintenance; airmanship; flying; and personnel. R.A.F. Quarterly, October, 1937, pages 388–395, 4 illus.

**Aviation Records.** List of world marks homologated by the Fédération Aéronautique Internationale, and recently established records awaiting official recognition. Aero Digest, December, 1937, pages 50, 52, 104, 106, 2 illus.

**Digest of Recent Record Flights.** Miss Batten's Australia-England flight. Distance record across the South Atlantic made by the Lieutenant de Vaisseau Paris. Altitude record of Cant Zappata 506-B seaplane (three 700-hp. Alfa Romeo 127 R.C.50 engines) which reached a height of 29,344 ft. with 2000 kg. load. Clouston-Kirby Green London-Cape flight. Wurster's 379.16-m.p.h. speed record in a Messerschmidt. Fuller Canada-Mexico record flight. Brief notes. Aero Digest, December, 1937, page 111.

**London—Cape Town—London.** Flight to Cape Town and back was made inside a week by A. E. Clouston and Mrs. Kirby Green. Account of flight and equipment of the D. H. Comet "Burberry." Aeroplane, November 24, 1937, pages 610–611, 2 illus.

Account of flight which covered 14,700 miles at 189 m.p.h. average speed. Flight, November 25, 1937, pages 512, 501.

**Aerolite Synthetic Glue.** Aerolite glue approved by the British Air Ministry for use in construction of aircraft. Advantages over natural and other synthetic glues, and procedure for using it. Engineering, December 24, 1937, page 723.

**The National Physical Laboratory.** Noise abatement in motor cars and aircraft, laboratory equipment and instruments for measurement of noise, acoustics of buildings, light-weight partitions, and sound insulation of floors and ceilings. Research being undertaken in the Physics Department. To be continued. Engineering, December 10, 1937, pages 644–647, 1 illus., 1 table.

**Records Made by Hanna Reitsch Flying the F.W.-61 Helicopter.** Further achievements of the Focke-Wulf F.W.-61 helicopter with references to its performance. Short note. Les Ailes, November 11, 1937, page 7.

**Interprovincial Congress of Aeronautical Engineering, Milan April 22–24.** Abstracts of the 15 papers given cover Italian research and comments on aircraft, engines, welding, brakes, radio, and medical research. L'Aerotecnica, August–September, 1937, pages 770–777.

**Research Reports and Memoranda.** Abstracts of N.A.C.A. reports and Luftfahrtforschung. Aircraft Engineering, November, 1937, pages 305–307.